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JOURNAL OF PALEONTOLOGY

PALEONTOLOGY

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VOLUME 32 MARCH, 1958 NUMBER 2

MIDDLE PENNSYLVANIAN SCHISTOCERATIDAE (AMMONOIDEA)

A. K. MILLER AND W. M. FURNISH
State University of Iowa, Iowa City

ABSTRACT—Triangularly coiled adolescent whorls have been described in the three more primitive genera of the Schistoceratinae. This peculiarity is most pronounced in *Paralegoceras* but is apparent in the ancestral *Diaboloceras*. Furthermore, it can be discerned in *Pintoceras*, a descendant. The development and decline of this phenomenon are traced, but its significance is uncertain. Comparable irregular coiling has been recorded in Devonian and Cretaceous genera, as well as in an unrelated Carboniferous form.

Representatives of the rare genus *Wellerites* are known from two areas in Texas, two in Oklahoma, one in Ohio, and one in the Southern Urals. Their age is invariably Desmoinesian. A study of the ontogenic development of the sutures reveals an ancestor in the Atokan of north-central Texas, *Bendites*, n. gen. This genus provides a link with a still more primitive member of the Welleritinae, *Winslowoceras* of the Lower Pennsylvanian.

INTRODUCTION

THE family Schistoceratidae had its inception in the late Lower Pennsylvanian and culminated in the Upper Pennsylvanian. Two subfamiles are recognized, the Schistoceratinae and the Welleritinae. The former includes the following genera: *Paralegoceras* and *Diaboloceras* (early Middle Pennsylvanian); *Pintoceras* (late Middle Pennsylvanian); and *Schistoceras* (Upper Pennsylvanian and ?Lower Permian). The Welleritinae consists of three genera: *Winslowoceras* (Lower Pennsylvanian), *Bendites*, n. gen. (early Middle Pennsylvanian), and *Wellerites* (late Middle Pennsylvanian). The suture is basically similar in all of these genera, but that of the later more advanced representatives consists of additional elements.

Acknowledgment is due to the following for making specimens available for study: L. M. Cline, M. K. Elias, E. A. Frederickson, Allan Graffham, L. R. Laudon, A. R. Loeblich, N. D. Newell, Walter Youngquist, and particularly the late John B. Owen. A type specimen of the type species of *Pintoceras* was loaned through the courtesy of John T. Lonsdale. Marvin Klaven and Frederick Leach helped prepare the illustrations. Various phases of the report were made financially possible by Graduate Research Funds of the State University of Iowa.

SYSTEMATIC PALEONTOLOGY

Family SCHISTOCERATIDAE Schmidt, 1929
Subfamily SCHISTOCERATINAE Schmidt

The genera placed in this taxon have sutures that form 10 to 14 primary lobes, of

UPPER
MIDDLE PENNSYLVANIAN
DESMOINESIAN
ATOKAN
LOWER
MORROWAN
Schistoceras
Pintoceras
Wellerites
Paralegoceras
Bendites
Diaboloceras
Branneroceras
Winslowoceras
Gastrioceras
PHYLOGENY
of the
SCHISTOCERATIDAE

TEXT-FIG. *1*

which the ventral one is prominently bifid. Ten lobes characterize the early Middle Pennsylvanian forms; late Middle Pennsylvanian species have 12, and those of the Upper Pennsylvanian 14. Details in the degree of complexity can be related to stratigraphic occurrence. However, the umbilical lobe is irregularly subdivided in *Pintoceras* and *Schistoceras*, with minor differences on opposite sides of the conch. Auxiliaries are added progressively in the umbilical region. The subdivisions of the ventral lobe are large and are subequal to the lateral lobes.

Primitive representatives have a more or less reticulate test, umbilical ribs, and a relatively wide umbilicus. More advanced forms tend to develop smooth narrowly umbilicate conchs. No two members of the phylogenetic sequence occur in direct association.

Middle Pennsylvanian Schistoceratinae seem to be largely limited to North America but are known to occur also in Europe, Asia, and Africa. *Paralegoceras* is widespread in the Atokan of the Midcontinent region. *Diaboloceras* has been found in beds of the same series in West Texas and Oklahoma. Stratigraphically, *Pintoceras* occurs chiefly in the late Middle Pennsylvanian Desmoinesian. Species have been described from the North American Midcontinent region and central Turkestan in Soviet Central Asia. *Schistoceras*, the best known genus of the subfamily, is a characteristic Upper Pennsylvanian ammonoid. The genus has been recorded from West Texas, the Midcontinent region, and the Eastern Interior of North America, as well as the Ural region. Plummer & Scott (1937, p. 255–257) also cite it from the Lower Permian of north-central Texas.

Pseudoschistoceras Teichert, 1944, of the late Paleozoic in Western Australia and the alleged *Schistoceras* from the Karakoram Range of Central Asia are probably not schistoceratids. *Paralegoceras alienum* Schmidt of the Ruhr lower Westphalian appears to be immature but lacks characteristic familial features. Also, it has been suggested that the single small poorly preserved specimen that serves as the basis for *Prehoffmannia* Plummer & Scott, 1937, may be a schistoceratid; however, it does not resemble any of the forms now under consideration, and we are uncertain as to its affinities.

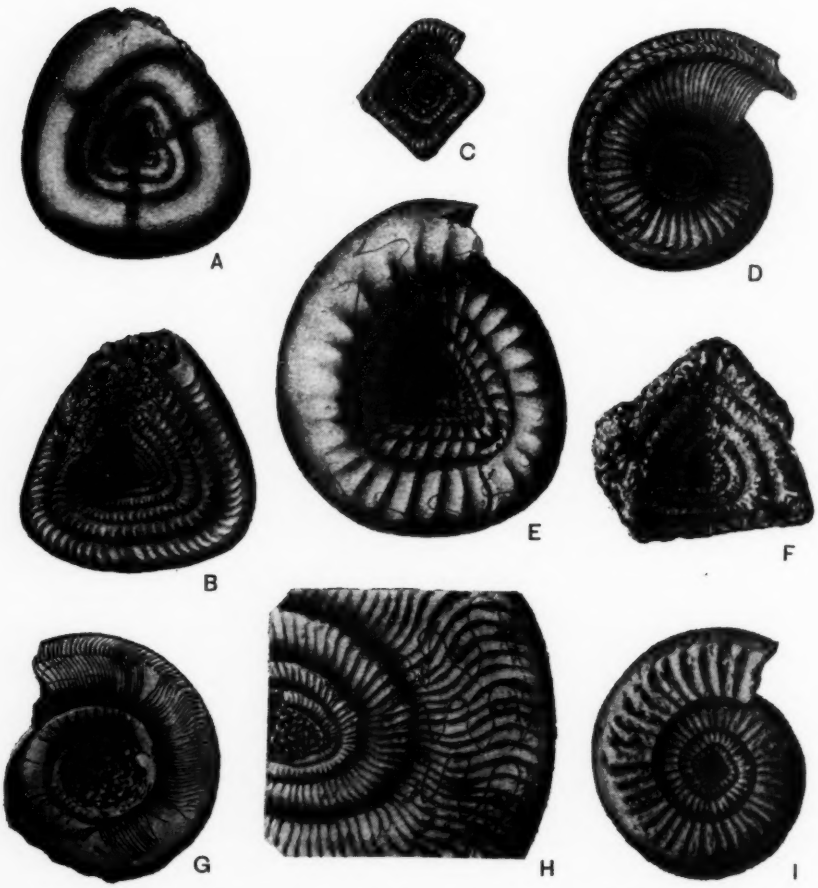
Triangular adolescent coiling.—Except for the typical genus, *Schistoceras*, all members of this subfamily have the early volutions of the conch more or less triangularly coiled. Although this peculiarity can be observed only in specimens with exceptional preservation, we have been able to document its widespread occurrence.

Comparable triangularly coiled whorls are known in some unrelated groups of ammonoids. As long ago as 1839, the phenomenon was noted in the clymenias, and Schindewolf (1937) has treated its occurrence there exhaustively. Several genera of these aberrant Upper Devonian cephalopods illustrate this feature, which has been shown to be characteristic of three distinct clymeniid stocks. The most spectacular development is in *Soliclymenia paradoxa* (Münster), represented by Text-figure 2B. This species is gradational with the regularly coiled *S. solarioides* (Buch), with which it occurs in direct association, and only a few triangularly coiled specimens have been found—Schindewolf was able to locate only five specimens, three in a single rock fragment.

Quadrangularly coiled adolescent whorls (Text-fig. 2C,D,I) occur in a Viséan genus, *Tetragonites;* originally described from Bosnia, then found abundantly in Westphalia, and more recently recorded from England, Morocco, Alaska, and Utah. The affinities of this form indicate no direct relationship to either the clymenias or the schistoceratids. A superficially similar quadrangular coiling in *Kamptoclymenia endogona* Schindewolf is sporadically developed.

Of the irregular coiling in various Mesozoic ammonoids, perhaps only one is analogous. That is, Spath (1936, p. 176) has mentioned, incidentally, the "triangular nepionic coiling of some" late Cretaceous *Schloenbachia*.

In the Schistoceratinae, this type of coiling is most pronounced in the genus *Paralegoceras* but is recognizable in both ancestral forms and postgenitors. An incipient stage of development is discernible in *Branneroceras* of the Lower Pennsylvanian (Pl. 34, fig. 6). In the early Middle Penn-



TEXT-FIG. 2—Representative Paleozoic ammonoids with irregularly coiled inner volutions.

A. *Kamptoclymenia trivaricata* Schindewolf. From the Upper Devonian *Wocklumeria* zone, Silesia, ×2. After Schindewolf.

B. *Soliclymenia paradoxa* (Münster). From the same horizon and locality as the preceding, ×2. After Schindewolf.

C, D. *Entogonites grimmeri* (Kittl). Figured type specimen, ×2, and immature whorls of another specimen, ×5, from the Middle Carboniferous near Sarajevo, Bosnia, Yugoslavia. After Kittl.

E. *Paralegoceras texanum* (Shumard). From the lower Atoka Formation near Clarita, Oklahoma (S.U.I. 13996), ×2.

F. *Paralegoceras? nopcsai* (Rakusz). From the Upper Carboniferous of Dobsina, Slovakia, ×10. After Rakusz.

G, H. *Winslowoceras percostatum* (Schmidt). *G*, Algerian specimen from the Westphalian of Gueltet Ahmed ben Salah, ×1; *H*, holotype from (?) Upper Namurian of La Camocha Mine near Gijon, Spain, ×2¾. After Termier, and Schmidt.

I. *Entogonites borealis* Gordon. Upper Mississippian Alapah Limestone on Kiruktagiak River Brooks Range, Alaska, ×2½. After Gordon.

sylvanian, the trend progressed in *Diaboloceras* (Pl. 34, fig. 10), which is intermediate between *Brannerоceras* and *Paralegoceras*. In 1940, we expressed the opinion that, in accordance with the principles of proterogenesis, "*Paralegoceras* may have prominently triangular descendants." However, it is now known that the stock continued into the Upper Pennsylvanian, but the peculiar coiling became less prominent, in *Pintoceras*, and then obsolete, in *Schistoceras*.

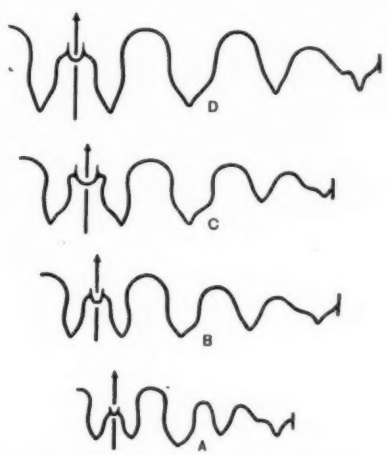
Another portion of the Schistoceratidae, the Welleritinae, developed contemporaneously, without irregular adolescent coils. A common ancestry with the Schistoceratinae is, however, indicated by the occurrence of incipient triangular coiling in the inner whorls of *Winslowoceras* of the late Lower Pennsylvanian (Pl. 33, fig. 10; Text-figs. 2G,H).

The significance of subangular bends in the early whorls of the conch has long been a subject for speculation. This irregularity does not seem to be comparable to that in the "heteromorphs" of the Mesozoic ammonites. Its appearance and persistence in more than one stock indicates that it is morphologic rather than pathologic or singular. Nevertheless, we are unable to suggest a logical purpose or function. Most of the so-called "ornamentation" or "sculpture" of the ammonoids resulted in a strengthening of the test, but subangular bends would presumably have weakened the conch. Any hypothesis proposed should take into consideration the fact that the body chamber occupied a full volution and that, except in some Devonian forms, the irregular coiling is confined to the inner volutions of the conch.

Genus PINTOCERAS Plummer & Scott, 1937

Types species: *P. postvenatum* P. & S., 1937.

Typical species of this genus have thickly subdiscoidal conchs that are subglobular during intermediate growth stages. The umbilicus is open and, though large in adolescence, becomes progressively smaller throughout ontogenetic development. The inner volutions of the conch are triangularly coiled and have prominent umbilical ribs.



TEXT-FIG. 3—Immature external sutures of *Schistoceras* and *Pintoceras*.

A. *S. hyatti* Smith. Presumably from the Upper Pennsylvanian Canyon Group, north-central Texas, ×6. From Plummer & Scott—the only figure these authors employed to portray their genus *Pintoceras*.

B. *P. turkestanicum* (Ruzhencev). From the Middle Pennsylvanian Jigulian Series, Turkestan Range, Central Asia, U.S.S.R.; at a diameter of 10½ mm., ×6. From Ruzhencev.

C. *P. unicum* (Miller & Owen). From the Seminole Formation, basal Missourian, Tulsa County, Oklahoma; based on the holotype (S.U.I. 13477), ×6.

D. *P. postvenatum* Plummer & Scott. From the Middle Pennsylvanian Strawn group, Kimble County, central Texas; based on figured homoeotype (Texas Bur. Econ. Geol., P-8586), at a diameter of 15 mm., ×5.

The surface of the test is reticulate. Each suture consists of a total of 12 deep lobes, of which the ventral one is prominently bifid. The subdivisions of this lobe, like the other lobes, are pointed and are subequal to the adjacent lateral lobes. The umbilical lobe is irregularly trifid. The saddles are rounded (Text-fig. 4D).

The ontogenetic development of the sutures in *Pintoceras* has been illustrated for American and Asiatic species (Miller & Owen, 1937, p. 421; Ruzhencev, 1952, p. 915). In both, the stages are virtually the same, though Ruzhencev's study was based on larger specimens and is more nearly complete. At a conch diameter of some 5 mm., the sutures of these two species pass through a *Paralegoceras* stage, and at 11 mm. they are precisely similar to that illustrated by Plummer & Scott (1937, p. 427, text-fig. 52c) as typifying *Pintoceras*. The latter is now known to represent an immature stage of the genus.

In 1940, we studied a large number of specimens of the Schistoceratinae, most of which came from the Upper Pennsylvanian. These revealed a considerable amount of gradational variation. We regarded a form from the Strawn of north-central Texas as being referable to *Schistoceras hildrethi* (Morton) originally described from the lower Conemaugh of Ohio. It is now apparent that typical *Schistoceras* is characterized by having the third lateral lobes located outside (ventrad of) the umbilical shoulders. On this basis, the Strawn species, but not true *S. hildrethi*, belongs in *Pintoceras*. There seems to be gradation between these two genera, though triangularly coiled inner volutions are not known in *Schistoceras*.

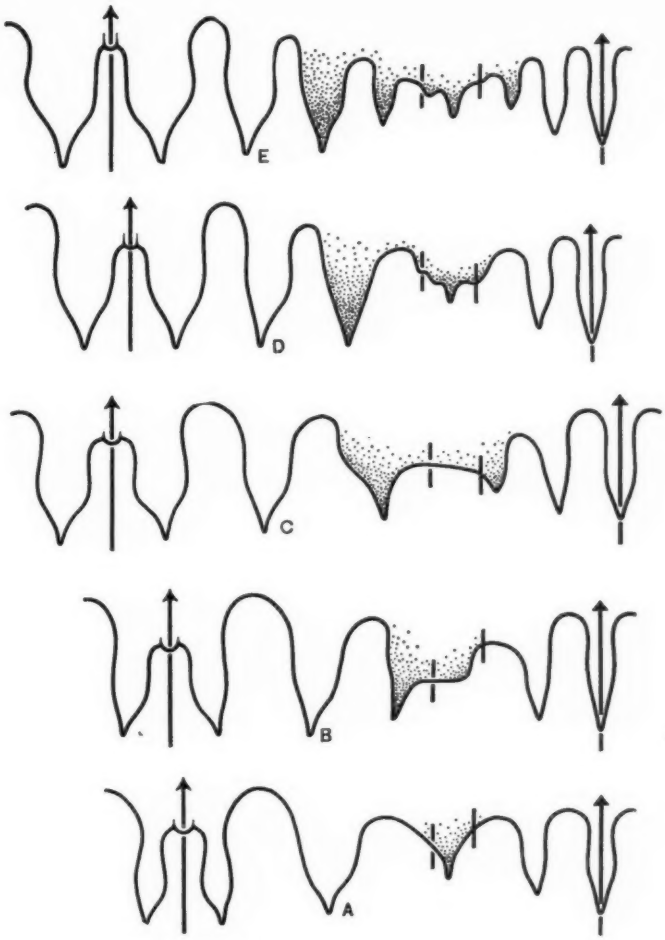
Altogether, four names have been proposed for species of *Pintoceras*. The type, *P. postvenatum*, is from the Strawn Group (Mineral Wells formation) of central and north-central Texas. *P. strawnense* (Plummer & Scott) of the same formation is probably conspecific. Furthermore, we now have available for study three specimens from the Desmoinesian Wewoka Formation at three localities in Oklahoma (Pontotoc, Hughes, and Okmulgee counties), and they are being referred to *P. postvenatum*. A somewhat more advanced species is *P. unicum* (Miller & Owen) of the lower Missourian Seminole Formation in northeastern Oklahoma. *P. turkestanicum* (Ruzhencev), from beds of about the same age in Central Asia, is similar to the American species.

When the genus *Pintoceras* was established, *P. postvenatum* was designated the type. This species was based on an unfigured fragment from southwest of Mineral Wells, Palo Pinto County, Texas, which is singularly stated "will have to serve as a type until a better preserved specimen can be found" (Plummer & Scott, 1937, p. 246). The only individual in the Plummer Collection that is labeled as the "holotype" of *P. postvenatum* is from a locality on the Llano River, Kimble County, some 150 miles to the southwest of the original locality. We are regarding it as typifying the species and as being a homoeotype, for it was collected by F. B. Plummer and presumably was identified by direct comparison with the holotype.

The homoeotype of *P. postvenatum* is moderately well preserved in limonite. Its inner volutions are triangularly coiled, and the umbilicus is large. The whorls are low and broad with umbilical ribs. The surface of the test bears transverse crenulate growth lamellae, which indicate the presence of a ventral sinus. An unfigured septate fragment, representing an additional whorl of the same specimen, shows that the umbilical ribs are obsolete at a diameter of some 30 mm. The sutures form a relatively small second lateral lobe on the umbilical shoulder, but the fragmentary outer volution shows a deeper lobe distinctly ventrad of the shoulder.

The published illustrations and description of the incomplete holotype of *Paraschistoceras strawnense* indicate that it is conspecific with the homoeotype of *Pintoceras postvenatum*. Both specimens are of about the same general size.

A relatively large individual, 80 mm. in diameter, from the Wewoka Formation of Oklahoma (Pl. 34, fig. 4) shows the mature characteristics of the species. The various measurements and proportions of this specimen are given in Table 1, where they are compared with those of related individuals. The available information suggests that the



TEXT-FIG. 4—A Pennsylvanian phylogenetic sequence from the Midcontinent region emphasizing progressive modification in the umbilical portion of the suture.

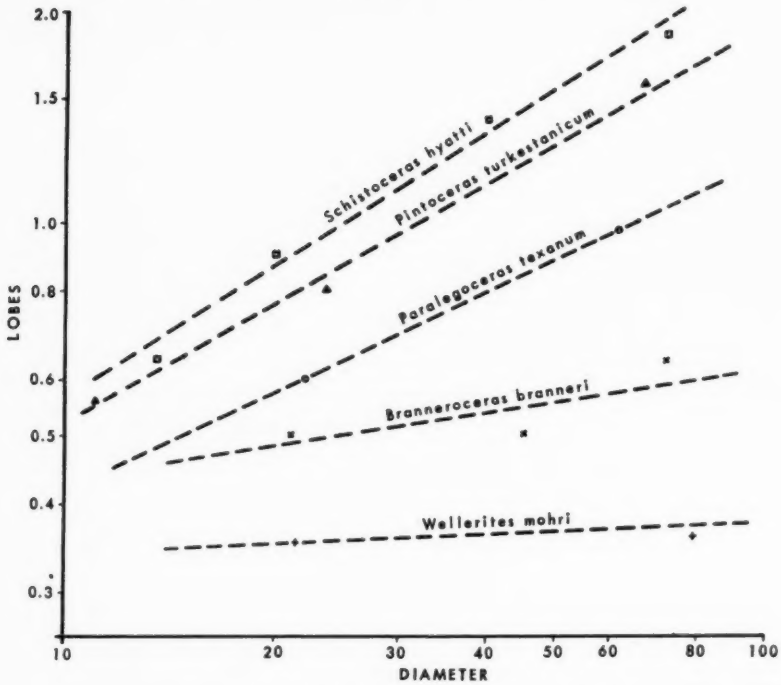
A. *Branneroceras branneri* (Smith). From the Lower Pennsylvanian Morrow Group, Boone County, northwestern Arkansas; based on a hypotype (S.U.I. 1975) at a diameter of about 45 mm., ×2.

B. *Diaboloceras varicostatum* Miller & Furnish. From the early Middle Pennsylvanian portion of the Magdalena Formation, Culberson County, West Texas; based on a syntype (S.U.I. 1416) at a diameter of some 60 mm., ×2.

C. *Paralegoceras iowense* (Meek & Worthen). From the Middle Pennsylvanian Cherokee Formation, Wapello County, Iowa; based on the holotype (Univ. Ill. 11098) at a diameter of about 80 mm., ×1¼. Details of internal sutures in part restored.

D. *Pintoceras postvenatum* Plummer & Scott. From the Middle Pennsylvanian Wewoka Formation, Hughes County, Oklahoma; based on a hypotype (S.U.I. 1962) at a diameter of 75 mm., ×1. Details of umbilical and internal portions of sutures somewhat restored.

E. *Schistoceras hyatti* Smith. From the Upper Pennsylvanian Graham Formation, Jack County, north-central Texas; based on a hypotype (S.U.I. 1059) at a diameter of 50 mm., ×1½. Details of umbilical and internal portions of sutures somewhat restored.



TEXT-FIG. 5—Diagram to illustrate relative growth in representative Schistoceratidae: diameter against the proportionate size of ventral prong of suture to first lateral lobe.

differences in the proportions of the inner and outer whorls are fairly constant within species.

The surface of the test of the large Wewoka specimen bears rather fine biconvex growth lines. Also, particularly on the umbilical portions of the lateral zones, there are relatively coarse and widely spaced longitudinal lirae. The suture (Text-fig. 4D) is characterized by a large prominently bifid ventral lobe. At maturity, the prongs of this lobe are considerably larger than the secondary ventral saddle which divides them and are appreciably larger than the first lateral lobes. The second lateral lobes are distinctly V-shaped.

The Seminole Formation (basal Missourian) of northern Tulsa County, Oklahoma,

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EXPLANATION OF PLATE 33

FIGS. *1–4—Pintoceras unicum* (Miller & Owen). Two topotypes (S.U.I. 1961) from the Seminole Formation south of Collinsville, Tulsa County, Oklahoma, ×4 and ×2½. *1*, Figure is reversed and actually represents opposite side of specimen.

5–9—Wellerites mohri Plummer & Scott. *5, 6*, Small specimen (S.U.I. 13845) which exposes inner volutions, from the Wewoka Formation about 7 mi. east of Ada, Pontotoc County, Oklahoma (sec. 4, T. 3 N., R. 7 E.), ×5; 7, large specimen (S.U.I. 1958) from the Buckhorn Asphalt about 3 mi. south of Sulphur, Murray County, Oklahoma (sec. 2, T. 1 S., R. 3 E.), ×1; *8, 9* specimen (S.U.I. 13844) from the Millsap Lake Formation about 1 mi. east of Millsap, Palo Pinto County, Texas, ×1.

10—Winslowoceras sp. A cast of the inner volutions (S.U.I. 1959) from the Lower Pennsylvanian of the Arbuckle region in south-central Oklahoma, ×3½.

11—Paralegoceras iowense (Meek & Worthen). Immature specimen (S.U.I. 1414) from the Smithwick Shale east of Rochelle, McCulloch County, Texas, ×3.

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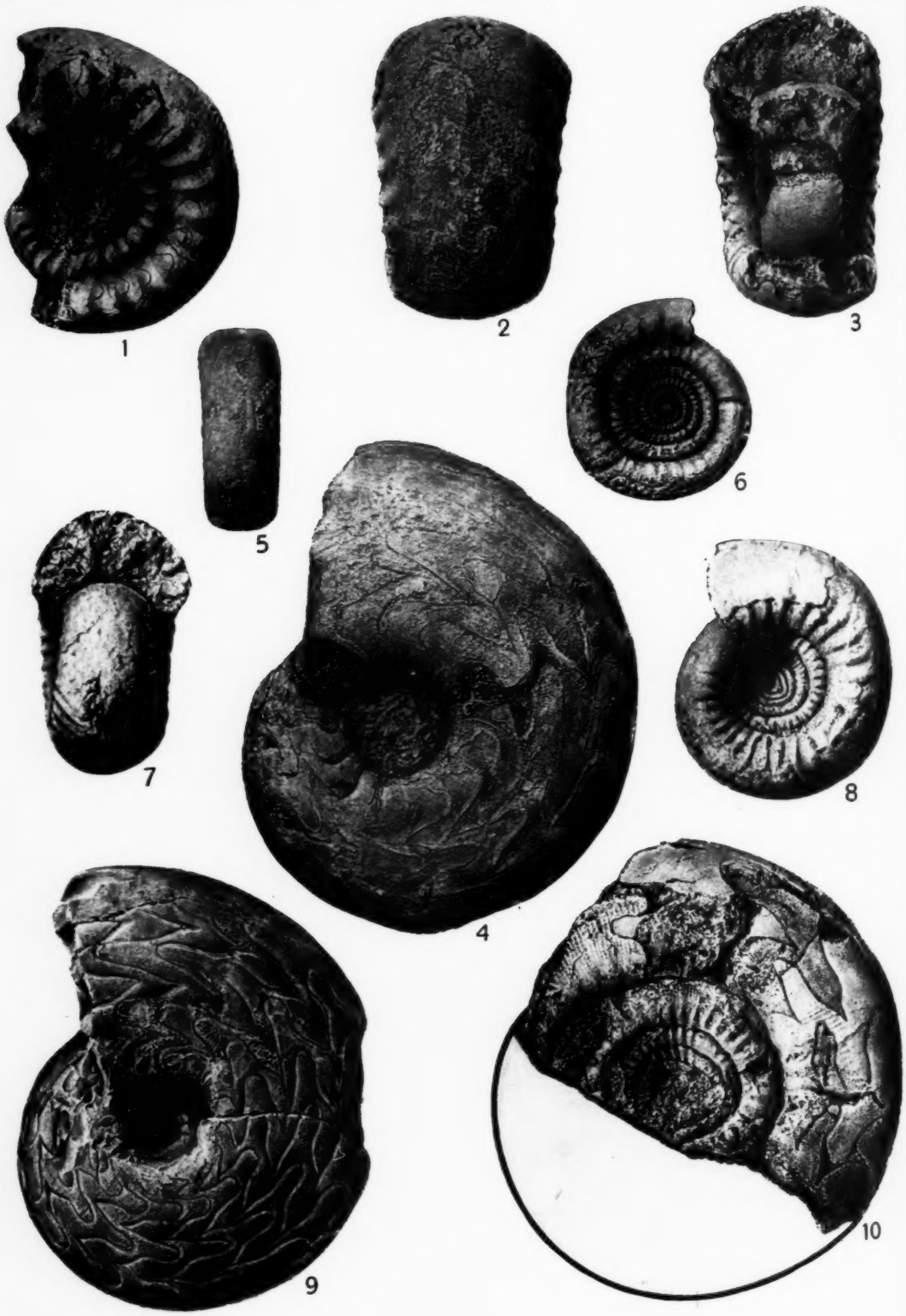
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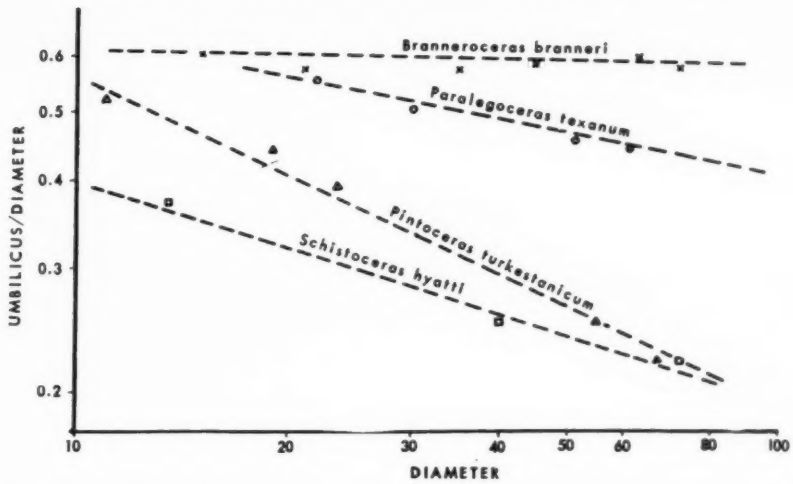


TEXT-FIG. 6—Diagram to illustrate relative growth in representative Schistoceratidae: diameter against the proportionate linear dimension of umbilicus to overall diameter.

carries *Pintoceras unicum* (Miller & Owen). That species was established in 1937 for a single fragment. More recently, Allan Graffham has sent us two conspecific specimens (Pl. 33, figs. 1–4). These show that the inner volutions of the conch are triangularly coiled and that this form is closely related to the type of *Pintoceras* but is somewhat more advanced. The most nearly complete specimen is of the same general size and proportion as the homoeotype of *P. postvenatum* (Table 1). All three of the known representatives of *P. unicum* have a ventral thickening of the test (intra-ventral carina of Elias, 1956, p. 129), which results in a groove on the internal mold, and this feature can therefore be regarded as a specific character, though it is known in certain other goniatite genera. The deposits became obsolete on the body chamber, and they are believed to represent a secretion on the inside of the shell, related to the development of septa. Because the body chamber was a full volution in length, the dorsal thickenings were resticted to the involute portion of the conch, where they may have served as ballast.

EXPLANATION OF PLATE 34

FIGS. *1–4*—*Pintoceras postvenatum* Plummer & Scott. *1–3*, three views of the homoeotype (Plummer Collection, Texas Bur. Econ. Geol., P-8586) from the Strawn Group northwest of Bierschwale ranch-house, Llano River, Kimble County, Texas, ×2½; *4*, large specimen (S.U.I. 1962) from the lower Wewoka Shale some 15 mi. south of Holdenville, Oklahoma (sec. 24, T. 5 N., R. 8 E.), ×1.

5,6—*Branneroceras branneri* (Smith). Immature specimen (S.U.I. 1973) from the Lower Pennsylvanian Hale Formation about 7 mi. southwest of Harrison, Arkansas (sec. 27, T. 18 N., R. 21 W.), ×5.

7,8—*Pintoceras turkestanicum* (Ruzhencev). Intermediate-sized specimen from the Middle Pennsylvanian Jigulian Series of the Turkestan Range, Central Asia, U.S.S.R., ×2. After Rushencev.

9—*Schistoceras hyatti* Smith. Specimen (S.U.I. 1059) from the Upper Pennsylvanian Finis Shale about 3½ mi. east of Jacksboro, Jack County, Texas, ×1.

10—*Diaboloceras varicostatum* Miller & Furnish. A composite specimen, part mold and part cast (S.U.I. 1418), from the Atokan Coody Sandstone near top of Briggs Mountain, southeast of Muskogee, Oklahoma, ×1.

TABLE 1—DIMENSIONS AND PROPORTIONS OF SCHISTOCERATIDAE AND RELATED FORMS. MEASUREMENTS ARE IN MM. Va/Li REFERS TO THE PRONG OF THE VENTRAL LOBE AND THE FIRST LATERAL

	Diameter	Width	Height	Umbilicus	W/D	U/D	Va/Li
Gastrioceras listeri (Sowerby)							
Coal Measures, Lancs. SUI 13717	20	14	7	11	.70	.35	.40
Coal Measures, Lancs. SUI 13716	43½	30½	14	25	.70	.58	±.50
Coal Measures, Lancs. from Ford Crick Br. Mus. C-4953	73½	63	23	45	.86	.61	.50
Coal Measures, Lancs. SUI 7694	94	62	34	44	.66	.47	—
Gastrioceras fittsi Miller & Owen							
Morrowan, Okla. SUI 13962	33½	23	9	20	.69	.60	.55
Morrowan, Okla. SUI 13960	67	47	20	33	.70	.49	.45
Morrowan, Okla. (Holotype) SUI 13959	±130	80	40	68	.62	.52	.60
Branneroceras branneri (Smith)							
Morrowan, Arkansas SUI 1955	6½	2½	1½	4½	.39	.69	±.30
Morrowan, Arkansas SUI 1977	15	7	3½	9	.47	.60	—
Morrowan, Arkansas SUI 1975	21	9	5	12	.43	.57	.50
Morrowan, Arkansas SUI 1976	35	15	9	20	.43	.57	—
Morrowan, Arkansas SUI 1976	45	19	12	26	.42	.58	.50
Morrowan, Oklahoma SUI 19355	63	22	16	37	.35	.59	±.50
Morrowan, Oklahoma SUI 13953	72	26	19	41	.36	.57	.64
Branneroceras halense (Miller & Moore)							
Morrowan, Arkansas SUI 1974	22	11	8	9	.50	.41	±.50
Morrowan, Arkansas SUI 1973	34	16	11½	15	.47	.44	—
Diaboloceras varicostatum Miller & Furnish							
Atokan, Oklahoma SUI 1418	62	±20	21	30	.32	.48	.67
Atokan, Texas SUI 1417	±150	56	60	—	.35	—	.68
Paralegoceras texanum (Shumard)							
Atokan, Oklahoma SUI 13996	22	12	6½	12	.55	.55	.60
Atokan, Oklahoma SUI 13997	30	14½	9	15	.48	.50	—
Atokan, Oklahoma SUI 13998	51	±16	17	23	.31	.45	—
Atokan, Oklahoma SUI 13998	61	±21	20	27	.34	.44	.98
Paralegoceras iowense (Meek & Worthen)							
Atokan, Texas SUI 1414	12	7	3	7½	.58	.62	±.40
Atokan, Texas SUI 1414	50	—	23	12	—	.24	—

TABLE 1—*Continued*

	Diameter	Width	Height	Umbilicus	W/D	U/D	Va/Li
Atokan, Oklahoma SUI 13999	65	22	28	18	.34	.28	1.00
Atokan, Iowa (Holotype) Univ. Ill. 11098	107	—	47	28	—	.26	1.12
Pintoceras postventum Plummer & Scott							
Desmoinesian, Texas Tex. Bur. P-8586	12	8	3½	7	.67	.58	—
Desmoinesian, Texas Tex. Bur. P-8586	20	12	6	10½	.60	.53	.61
Desmoinesian, Texas, *P. strawnense* (Holotype) Tex. Chr. Univ., from P. & S.	24½	—	10½	11	—	.42	±.64
Desmoinesian, Okla. SUI 1962	87	±39	41	18	.45	.21	1.30
Pintoceras turkestanicum (Ruzhencev)							
Jigulian, USSR from Ruzhencev	11	6½	3	5½	.58	.52	.56
Jigulian, USSR from Ruzhencev	19	11½	6	8½	.60	.44	—
Jigulian, USSR from Ruzhencev	23½	15	8½	9½	.62	.39	.80
Jigulian, USSR from Ruzhencev	55	29	27	14	.53	.25	—
Jigulian, USSR from Ruzhencev	67	36	32½	14½	.53	.22	1.56
Pintoceras unicum (Miller & Owen)							
Missourian, Okla. SUI 1961	8	4½	2	5	.56	.63	±.40
Missourian, Okla. SUI 1961	10	6	2½	6	.60	.60	±.45
Missourian, Okla. SUI 1961	16	10	5	7½	.63	.47	.60
Missourian, Okla. SUI 1961	20	13	7½	11	.65	.55	.95
Schistoceras hildrethi (Morton)							
Missourian, Pennsylvania SUI 3114	26	16	9½	11½	.62	.44	.81
Missourian, Pennsylvania SUI 3115	32	18½	13	12	.58	.38	1.05
Virgilian, Texas SUI 5966	7½	3½	2	4	.47	.53	—
Virgilian, Texas SUI 1897	20½	13	8	10½	.65	.51	—
Virgilian, Texas SUI 1897	31	20	12½	13½	.65	.44	1.05
Virgilian, Texas SUI 1897	40	24	19	14½	.60	.36	1.10
Schistoceras missouriense (Miller & Faber)							
Missourian, Ohio SUI 1437	40	21	18½	10	.53	.25	1.35
Missourian, Missouri SUI 13988	58	30	28½	13½	.49	.23	1.60
Schistoceras hyatti Smith							
Virgilian, Texas SUI 13833	7½	5	2½	4	.67	.53	.30
Virgilian, Texas SUI 1897	13½	9½	6	5	.70	.37	.64

TABLE 1—*Continued*

	Diameter	Width	Height	Umbilicus	W/D	U/D	Va/Li
Virgilian, Texas SUI 1897	20	13	11	5	.65	.25	.90
Virgilian, Texas SUI 1059	40	22½	21	10	.56	.25	1.39
Virgilian, Texas SUI 1059	72	35	35½	15½	.49	.22	1.84
Virgilian, Texas SUI 5967	±110	—	56	22	—	.20	2.00
Winslowoceras henbesti Miller & Downs							
Morrowan, Arkansas USNM (Holotype)	73	±16	25	29	.22	.40	.23
Winslowoceras percostatum (Schmidt)							
Upper Namurian, Spain from Schmidt	30	—	10	14	—	.47	.36
Bendites moorei (Plummer & Scott)							
Atokan, Texas Tex. Bur (Holotype)	33	11½	6½	12	.37	.36	.30
Wellerites mohri Plummer & Scott							
Desmoinesian, Oklahoma SUI 13845	8	3½	3	3	.44	.38	.48
Desmoinesian, Texas SUI 1956	21½	7½	10½	6½	.35	.30	.35
Desmoinesian, Texas SUI 13844	79	±20	32	±26	.25	.33	.36
Desmoinesian, Oklahoma SUI 1958	132	±28	51	40	.21	.30	.39
Desmoinesian, Texas, from P. & S. Tex. Bur. P-2405	29	6½	16	?6	.22	?.21	.24
Mid. Carboniferous, USSR from Ruzhencev	—	15	30	—	—	—	.32

The published information in regard to *P. turkestanicum* indicates that it does not differ materially from the American species. It was based on five specimens from the nothern foothills of the Turkestan Range, south of Kara Tau.

Subfamily WELLERITINAE Plummer & Scott, 1937

Winslowoceras, the most primitive representative of this subfamily, is rare but is known from the Lower Pennsylvanian of the Arkansas-Oklahoma region (Elias, 1956, p. 95,100,101). *Paralegoceras percostatum* Schmidt of the Algerian-Moroccan borderland (Termier, 1950, p. 71, pl. 156, figs. 16,17) and of nothern Spain is probably a somewhat more advanced representative of the same genus. *P. alienum* Schmidt of the Ruhr region appears to be only superficially similar (Schmidt, 1955, p. 51). *Bendites*, n. gen., is based on a single specimen from the early Middle Pennsylvanian of north-central Texas. *Wellerites*, the end member of the phylogenetic series, is known from Middle Pennsylvanian strata of three general localities in United States and one in the Ural region.

Genus WELLERITES Plummer & Scott, 1937

Type species: *W. mohri* P. &. S., 1937.

Notwithstanding the intensive consideration that has long been accorded Middle Pennsylvanian goniatites, the distinctive *Wellerites* was not recorded until 1937. At that time, the stratigraphic occurrence of the single specimen was uncertain. However the

question was soon clarified, and the genus is now believed to be limited to beds of Desmoinesian age. Although representatives are generally rare, they are of widespread occurrence in this country, and one is known from the Ural region.

The original type specimen came from an isolated outcrop of Carboniferous strata near the western margin of the Llano region in central Texas. The late Paleozoics there consist of several formations lying between the Ordovician Ellenburger limestone and the Cretaceous Edwards limestone. The *Wellerites* bed was at first believed by Plummer & Scott (1937, p. 15) to be part of the Upper Mississippian Barnett Formation. Soon, however, these authors (1938, p. 1919–1920) secured representatives of the genus from the Millsap Lake Group (Strawn Series) of north-central Texas and therefore concluded that the holotype is likewise of Middle Pennsylvanian age. Although the additional material was never illustrated or described, the Millsap Lake has yielded other well preserved representatives of *Wellerites* (Pl. 33, figs. 8,9).

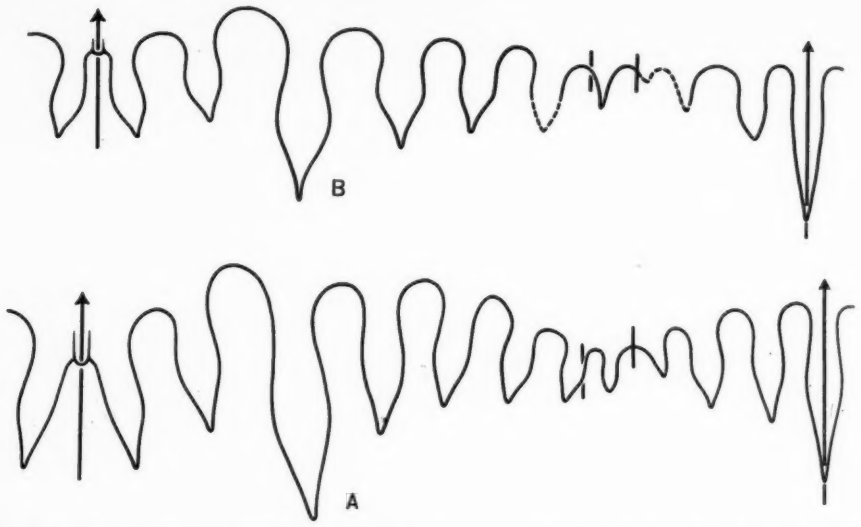
Congeneric specimens were described by Smith in a report issued in 1938. They came from the Buckhorn Asphalt of the Oklahoma Arbuckle region and are presumably of about the same age as the Millsap Lake collections. Some of the Buckhorn individuals attain large proportions (Pl. 33, fig. 7) but are nevertheless conspecific with the the type. Somewhat to the northeast, in McAlester basin, the same species occcurs in the Wewoka Shale in association with a large variety of goniatites and other fossils. The fauna of that formation was described in detail by Girty (1915), who, however, did not record the occurrence of *Wellerites* in it. Only two fragmentary specimens of this genus are known from the Wewoka, and both of them came from a locality not represented in Girty's collections. Two poor specimens have been described from the Allegheny Series (Vanport and Hamden limestones) of easternmost Ohio. They may be unidentifiable specifically but do not appear to differ significantly from the type. A single fragment of *Wellerites* is also known from the Ural region (Ruzhencev, 1952). The published illustrations suggest that it likewise may represent the same species.

WELLERITES MOHRI Plummer & Scott
Pl. 33, figs. 5–9; text-figs. 7,8

Wellerites mohri PLUMMER & SCOTT, 1937, Texas Univ. Bull. 3701, p. 376,377–378, pl. 38, figs. 13–16; —— 1938, Geol. Soc. America, Bull. v. 49, p. 1920; SHIMER & SHROCK, 1944, Index foss. N. America, p. 575, pl. 236, figs. 7,8; MILLER & STURGEON, 1946, Jour. Paleontology, v. 20, p. 388; MILLER & FURNISH, 1957, Moore Treatise, Pt. L, p. 66, text-figs. 99,100.
Walkerites mohri SMITH, 1938, The cephalopod fauna of the Buckhorn asphalt, p. 32.
Walkerites plummeri SMITH, 1938, ibid., p. 32–33, pl. 2, figs. 22,23
Walkerites vulgaris SMITH, 1938, ibid., p. 31–32, pl. 2, figs. 24,25.
Wellerites sp., MILLER & STURGEON, 1946, Jour. Paleontology, v. 20, p. 387–389, pl. 56, figs. 6–9; UNKLESBAY, 1954, ibid., v. 28, p. 85,86,91, 92.
?Wellerites russiensis RUZHENCEV, 1952, Akad. Nauk SSSR, Doklady, t. 84, p. 133–134.

The material now available is adequate for an understanding of this species. The conch is discoidal; phragmocone attains a diameter of at least 135 mm. (Pl. 33, fig. 7) and a corresponding width of some 30 mm. (estimated)—all our large specimens are crushed and appear to represent only about two-thirds the true transverse dimension. Diameter of umbilicus is a third that of conch, and shoulders are rounded. Length of body chamber unknown, but is a full volution in related forms.

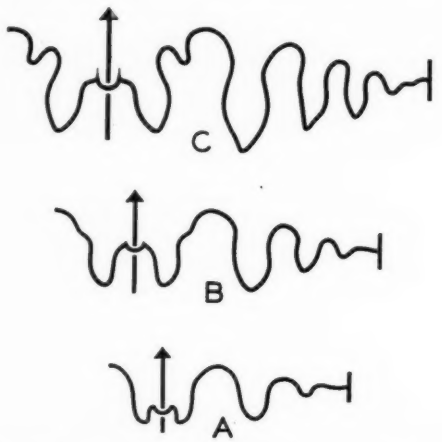
Inner whorls bear prominent transverse umbilical ribs, which become obsolete at a conch diameter of about 10 mm. Orad of a diameter of some 25 mm., is a submedian sulcus which becomes more prominent adorally; where conch is 45 mm. high, sulcus is 4 mm. wide and 1 mm. deep. On mature portion of conch, growth lines show that apertural margins bore prominent rounded lappets with subparallel flanks. At conch height of 50 mm., these lappets are some 20 mm. long and 15 mm. wide. There are 6 distinct longitudinal lirae on the lappet-portion of the test. Growth lamellae are prominent on the umbilical and ventral zones, but no trace is discernible on the internal mold. They form rounded lateral and deep ventral sinuses. Transverse growth lamellae are prominent on inner volutions of conch, where they form rounded ventrolateral salients rather than lappets. At a conch diameter of 100 mm., the ventral and ventrolateral portions of the test are less than 1



TEXT-FIG. 7—Complete sutures of *Wellerites mohri* Plummer & Scott. *A*, Based on a specimen (S.U.I. 13843) at a diameter of 65 mm. from the Millsap Lake Formation east of Millsap, Palo Pinto County, Texas, ×2; *B*, specimen from Moscovian of the Chkalov region in the Southern Urals tentatively identified with this species, ×2, after Ruzhencev.

mm. in thickness. The septal necks are long and become prochoanitic during early ontogenetic development.

Text-figure 7A illustrates the complete mature suture. The saddle which divides the ventral lobe is nearly as high as that lobe is deep. Each prong of the ventral lobe is about the same size and shape as the adjacent adventitious lobe and is less than half the size of the next lobe, the first lateral. The following four lobes of the external suture are subequal but constitute a gradational series. The internal suture consists of a deep narrow dorsal lobe and, on either side of it,



TEXT-FIG. 8—*Wellerites mohri* Plummer & Scott. External sutures during early ontogenetic development, based on specimen (S.U.I. 13845) from the Wewoka Formation, east of Ada, Oklahoma. *A*, represents a conch diameter of 3½ mm., ×14; *B*, a diameter of 5 mm., ×11; and *C*, a diameter of 7½ mm., ×10.

three internal lateral lobes that are progressively shorter and relatively wider. These internal lateral lobes are paired as septal flexures with the auxiliary (3rd to 5th lateral) lobes of the external suture, and a small additional intermediate lobe is developed on the umbilical wall.

At a conch diameter of 3 mm., there is no indication of an adventitious lobe in the first lateral saddle. However, immediately thereafter, the oral portion of the ventral flank of that saddle becomes slightly flattened (Text-fig. 8A). By a diameter of 5 mm., a distinct lobe has developed from the flattened part of the saddle (Text-fig. 8B). During later ontogenetic development, that lobe becomes relatively large and more nearly median in position within the saddle.

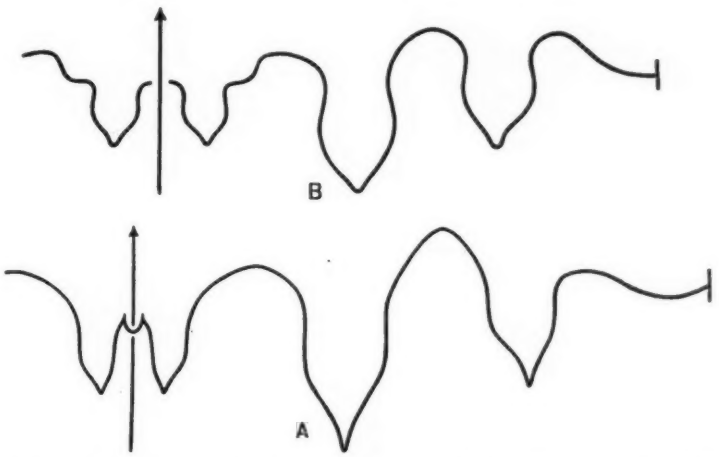
The occurrence of this species is given in the generic discussion. It is almost invariably rare, but we have 8 limonitic internal molds from the Millsap Lake Formation of Texas and 5 testiferous specimens from the Buckhorn Asphalt of Oklahoma. Smith (1938, p. 32) recorded a "large number" from the latter.

Genus BENDITES Miller & Furnish, n. gen.

Type species: *Bendoceras moorei* Plummer & Scott, 1937.

The basis for this genus is virtually a single specimen, which, as mentioned by Plummer & Scott (1937, p. 209), differs materially from all other described forms. The published data indicate that the conch is discoidal, being somewhat compressed and consisting of whorls that are flattened laterally and rounded ventrally. The typical specimen is about 33 mm. in diameter and represents only half of two volutions but retains traces of the internal sutures of an additional whorl. The umbilicus is moderately large, and there is a series of umbilical ribs on the shoulders of the penultimate whorl of the figured type. Each suture consists of a relatively small bifid ventral lobe and on either side of it two subequal pointed-spatulate lateral lobes and a broad rounded umbilical lobe. The internal suture has not been illustrated or described in detail, but on a published illustration of the type species (Plummer & Scott, 1937, pl. 11, fig. 14) it can be observed that the dorsal lobe is laceolate. The most distinctive character of the suture is the presence of small adventitious lobes in the adoral portion of the ventral flank of the first lateral saddles (Text-fig. 9B).

Although this genus is related to *Paralegoceras* [= *Bendoceras*], it is not in the same line of evolution as the typical schistoceratids. Instead it represents an intermediate



TEXT-FIG. 9—Mature external sutures of the type species of *Winslowoceras* and *Bendites*.
A. *W. henbesti* Miller & Downs. From the Lower Pennsylvanian Morrow Group at Winslow, Arkansas; based on primary type specimens at a diameter of about 60 mm., ×3.
B. *B. moorei* (Plummer & Scott). From the Middle Pennsylvanian Smithwick Shale, McCulloch County, Texas; based on holotype at a diameter of some 25 mm., ×4½. After Plummer & Scott.

stage between *Winslowoceras* and *Wellerites* and together with them constitutes the Welleritinae. This subfamily is characterized by a discoidal conch, with rather prominent ventrolateral salients, and a relatively small bifid ventral lobe of the sutures.

The holotype of *Bendites moorei* came from the Smithwick shale in McCulloch County, north-central Texas. Plummer & Scott indicate that the same species occurs n equivalent beds of the Sierra Diablo, West Texas. There are no representatives in our rather extensive collections from these two localities.

Note.—Additional information has become available since this manuscript was written and submitted for publication. *Eowellerites* Ruzhencev, 1957, a name introduced in a footnote [Moskov. Obshch. Ispyt. Prirody, Byull., Otd. Geol., t. 32, p. 55] to a short paper on goniatite classification, is an objective synonym and will, of course, take precedence over *Bendites*, proposed here. Also, Mackenzie Gordon, Jr., has advised us that he has encountered the genus, as well as a related form, in the Atoka Formation of Oklahoma; this occurrence is to be described by him in a manuscript now nearing completion.

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GONIATITES OF THE BURLINGTON LIMESTONE IN MISSOURI

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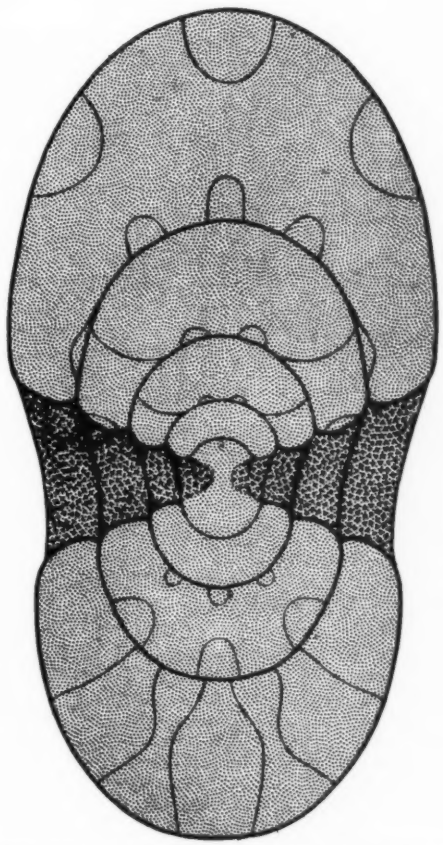
ABSTRACT—Two species of ammonoids are illustrated and described from the Burlington Limestone (Lower Mississippian) in Missouri. One of these, *Muensteroceras? mitchelli* Miller, is known from a single individual found in Cooper County in the central part of the state. The name *M. rowleyi*, n. sp., is based on several specimens from Louisiana, northeastern Missouri.

THE Burlington Limestone (Osagian) of the Upper Mississippi Valley carries an abundance of fossils, but it has yielded only a few ammonoids. The late R. R. Rowley of Louisiana, Missouri, collected about half a dozen specimens from the lower part of the formation in the vicinity of his home town in Pike County. In this area, the Burlington consists of about 100 feet of cherty crinoidal limestone. The specimens are preserved in white chert, and only the general horizon and locality are now available. Over 100 miles to the southwest, a single ammonoid was found in about the same stratigraphic position at the well-known Sweeney railroad quarry, Cooper County, where only the lower Burlington is exposed above the Kinderhookian. In this case, preservation is in light-brown calcarenite. These few goniatites are all the Burlington specimens that are now available. *M.? osagense* (Swallow), listed from the Burlington, is actually a poorly known Kinderhook species. The original types were never illustrated, and they, as well as Smith's hypotype (1903, p. 119), have been lost. Even the generic reference is doubtful. Only one suture drawing, Smith's, exists, and it shows a wide ventral lobe; whereas the type species of *Muensteroceras* has a narrow lobe at the same growth stage.

Locally, ammonoids are abundant and well preserved in the Kinderhookian, but most of them represent only a few general types: imitoceratids, muensteroceratids, and prolecanitids. In the Midcontinent, only poorly preserved isolated individuals have been found in the basal Osagian, approximate Burlington equivalent. The St. Joe Limestone of southwestern Missouri has yielded a single specimen of *Muensteroceras*, and from the overlying Reeds Spring we know a fragment of *Merocanites*. The only known representative of *Beyrichoceras hornerae* Miller is probably also from the Reeds



TEXT-FIG. 1—*Muensteroceras parallelum* (Hall). Cross section of a representative of the type species (State Univ. Iowa, 5968) from the original locality at Rockford, Indiana, ×5. The innermost whorls are not preserved.

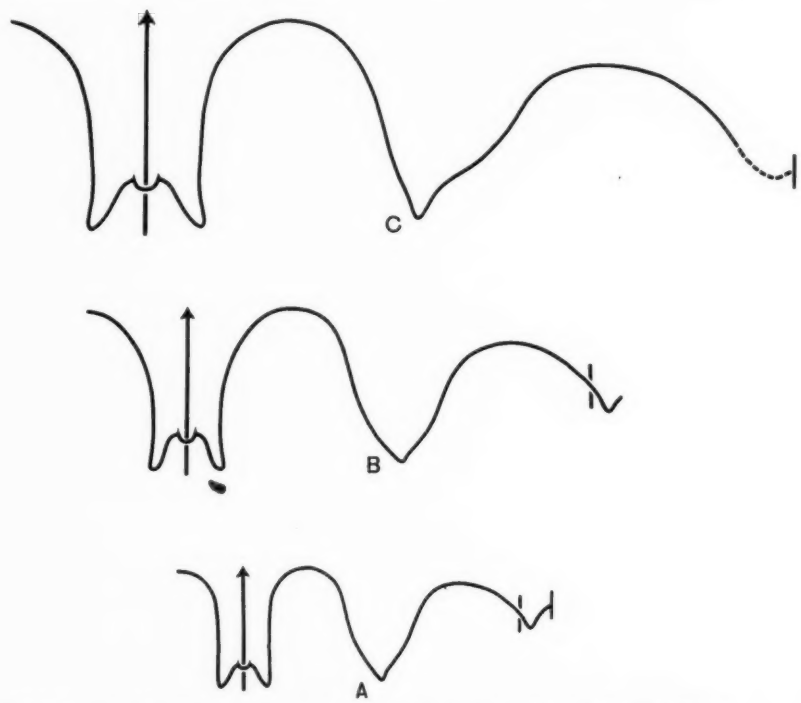
Spring; *Beyrichoceras* is the zone fossil of the Middle Viséan in Europe. Near St. Louis, the approximately equivalent Fern Glen Formation has produced the holotype of *Muensteroceras pfefferae* (Miller & Werner) and that of *M. eshbaughi* (Miller, Downs, & Youngquist).

The New Providence and overlying Brodhead formations of central Kentucky have yielded goniatites. *Merocanites* is represented in both. In the older, it occurs in association with abundant *Pericyclus*, which is characteristic of the Eurasian lower Viséan. The New Providence is generally considered to be of about the same age as the Burlington, but the goniatites of the two show no similarity, possibly because of a difference in facies. East of Kentucky, in western Virginia, a fragmentary specimen of *Muensteroceras* has been found somewhat below the middle of the Price Formation (Text-fig. 2C); it is too small and poorly perserved to permit specific comparisons.

Genus MUENSTEROCERAS Hyatt, 1884

Type species: *Goniatites oweni parallela* Hall.

This genus includes all the goniatites known from the Burlington in its type region. Although widely distributed and everywhere characteristic of the Kinderhookian-Tournaisian, *Muensteroceras* ranges up into the Osagean-Viséan.

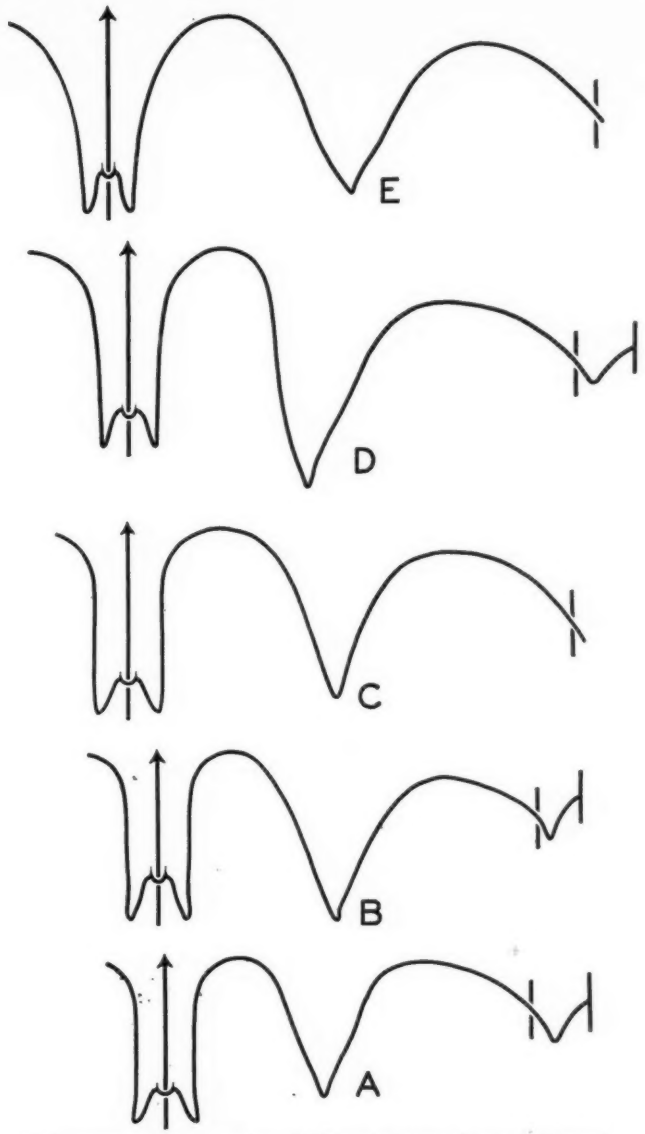


TEXT-FIG. 2—External sutures of three species of *Muensteroceras*, small specimens.

A. *M. parallelum* (Hall). A topotype (State Univ. Iowa, 5968) from the Rockford Limestone of Rockford, Indiana, at a diameter of 10 mm., ×6. This type species illustrates proportions characteristic of the genus even at this small size.

B. *M. medium* Miller & Collinson. The holotype (State Univ. Iowa, 6798) from the Northview Formation north of Springfield, Missouri, at a diameter of 15 mm., ×6.

C. *M.* sp. A specimen (State Univ. Iowa, 9546) from the Price Formation on Draper Mountain, Pulaski County, Virginia, at a diameter of ca. 18 mm., ×7. B. N. Cooper secured this individual 375 feet above the base of the formation on U. S. Hwy. 11 at the town of Pulaski; it is preserved in limonitic argillaceous sandstone. Details have been slightly adjusted to compensate for obvious distortion during preservation.



TEXT-FIG. 3—External sutures of five species of *Muensteroceras*, large specimens.

A. *M. rowleyi*, n. sp. The holotype (Univ. Ill.) from the lower Burlington Limestone of Louisiana, Missouri, at a diameter of 45–50 mm., ×2.

B. *M. parallelum* (Hall). The type species from the original locality (State Univ. Iowa, 1086) at a diameter of 33 mm., ×2½.

C. *M. eshbaughi* (M., D. & Y.). The holotype (State Univ. Iowa, 8050) from the type Fern Glen at a diameter of ca. 45 mm., ×2½. Specimen poorly preserved and drawing probably not in true proportion.

D. *M.* sp. Based on the distorted specimen figured by Miller & Collinson in 1952 (State Univ. Iowa, 1910) from the St. Joe Formation of Barry County, Missouri, at a diameter of ca. 75 mm., ×1½.

E. *M.? mitchelli* Miller. The holotype (Univ. Mo., 6694) from the lower Burlington Limestone, Cooper County, Missouri, at a diameter of 60–65 mm., ×2. Certain of the details are obscure.

Several other genera have been proposed for variants (Bisat, 1952). The proportions of the ventral lobe of the sutures are regarded as critical. In *Beyrichoceras* Foord, that lobe is relatively wide and its prongs diverge. *Beyrichoceratoides* and *Bollandites*, both of Bisat, are so closely similar to *Muensteroceras* that they should probably be regarded as synonyms of it, though they occur in association with early representatives of *Goniatites* and are therefore younger, being middle-upper Viséan in age. The type species of *Bollandites* is *Beyrichoceratoides castletonensis*, the holotype of which came from an unknown locality.

MUENSTEROCERAS? MITCHELLI Miller
Pl. 35, figs. 12,13

?Muensteroceras? osagense MOORE, 1928, Missouri Bur. Geology, Mines, ser. 2, v. 21, p. 187,206; BRANSON, 1944, Missouri Univ. Stud., v. 19, no. 3, p. 233.
Münsteroceras mitchelli MILLER, 1935, Am. Jour. Sci., v. 230, p. 435–437; BRANSON, 1944, Missouri Univ. Studies, v. 19, no. 3, p. 233; MOORE, 1948, Jour. Geology, v. 56, p. 399.
Bollandites? mitchelli GORDON, 1957, U. S. Geol. Survey, Prof. Paper 283, p. 37.

The holotype of this species is a rather poorly preserved internal mold composed of typical Burlington Limestone, crinoidal detritus. It is septate throughout, is about 75 mm. in diameter, and was some 35 mm. in width before one side was reduced by weathering. The diameter of the umbilicus is approximately a fifth that of the conch.

The surface of the mold is not preserved in detail, but the external volution retains a portion of one transverse constriction. The suture is not similar to that of typical *Muensteroceras*, because the sides of the ventral lobe are slightly divergent (Text-fig. 3E).

Remarks.—The distortion and poor preservation of this specimen prohibit more than approximate comparisons with other species. Nevertheless, the ventral portion of the suture is quite distinctive; the diverging sides of the ventral lobe make the generic reference doubtful.

Occurrence.—About 30 feet above base of Burlington Limestone in Sweeney railroad quarry, 2½ mi. northeast of Clifton City, Cooper County, Missouri (SE¼, sec. 4, T. 46 N., R. 19 W.). Both Moore and Branson list a Chouteau species, *M.? osagense*, from white chert 30–40 feet above the base of the Burlington west of Osceola, St. Clair County, Missouri. Their material may belong in the species under consideration, but we have not been able to locate it.

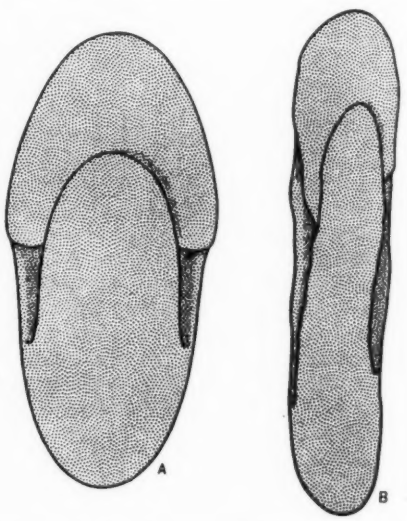
Holotype.—Univ. Missouri, 6694.

MUENSTEROCERAS ROWLEYI M. & F., n. sp.
Pl. 35, figs. 1–9

Goniatites osagensis [part] KEYES, 1894, Missouri Geol. Survey, v. 5, p. 221; KEYES & ROWLEY, 1897, Iowa Acad. Sci., Proc., v. 4, p. 36.
Goniatites? spp. [part?] KEYES & ROWLEY, 1897, ibid.; ROWLEY, 1908, Missouri Bur. Geology Mines, ser. 2, v. 8, p. 42.
Muensteroceras? osagense [part] SMITH, 1903, U. S. Geol. Survey, Mon. 42, p. 14,145.
Münsteroceras spp. MILLER, 1935, Am. Jour. Sci., v. 230, p. 433–434; BRANSON, 1944, Missouri Univ. Studies, v. 19, no. 3, p. 233.

This species is based on several specimens, and that represented by Pl. 35, fig. 1, is designated the holotype (Text-fig. 5). All are preserved in white "chalky" chert.

An unfigured portion of the holotype



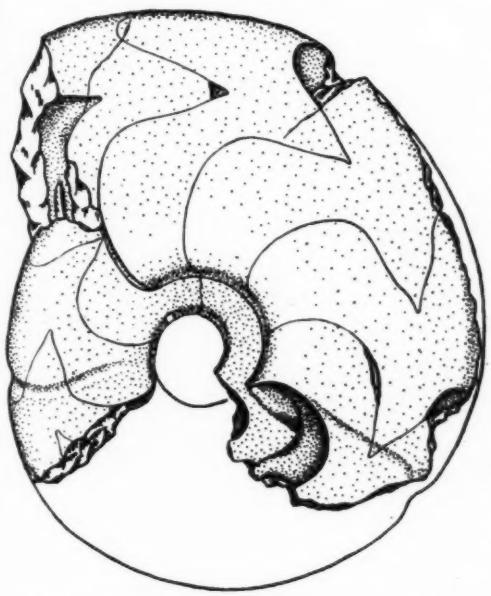
TEXT-FIG. 4—Diagrammatic ventral profiles of two lower Osagian species of *Muensteroceras* from Missouri.
A. *M. rowleyi*, n. sp., based primarily on the holotype (Univ. Ill.) from the lower Burlington, ×1½.
B. *M. eshbaughi* (M., D. & Y.), based on the crushed holotype (State Univ. Iowa, 8050) from the type Fern Glen, ×1.

shows that the conch attained a diameter of more than 75 mm. Where the phragmocone is 50 mm. in diameter, its whorls are about 25 mm. wide and 23 mm. high. The umbilical diameter is about a fifth that of the conch (Text-fig. 4A). The most nearly complete of the paratypes (Pl. 35, figs. 8,9) is about 43 mm. in diameter, and its outer whorl reaches a width and height of conch of 21 mm. and 20 mm., its umbilicus a diameter of 11 mm.

The surface of the internal mold bears rather prominent traces of the growth lines and 4–6 rounded constrictions to a volution. Both of these markings are almost straight and directly transverse on the lateral zones but form moderately deep ventral sinuses.

The shape of the sutures is well illustrated by the holotype (Text-fig. 3A). The sides of the ventral lobe are nearly parallel, and the lateral lobes are V-shaped. The internal sutures form three long slender pointed lobes like those of other representatives of *Muensteroceras*.

Remarks.—The holotype is rather fragmentary, but it is supplemented by the paratypes. All seem to be closely similar in their several characteristics.



TEXT-FIG. 5—*Muensteroceras rowleyi*, n. sp. Diagrammatic representation of the holotype (Univ. Ill.), a portion of which is shown by Pl. 1, fig. 1; from the lower Burlington at Louisiana, Missouri, ×1½.

The specimen represented by Pl. 35, figs. 10,11, is preserved in glossy yellow translucent chalcedony, and it appears to be quite distinct from the others in the collection. It has been crushed laterally but may well have been of approximately the same proportions as the associated individuals. This specimen could have been the basis for the alleged occurrence of "*Goniatites* sp.?" in the upper Burlington at Louisiana.

M. rowleyi resembles the type species of the genus *Muensteroceras*, *M. parallelum* (Hall), in which, however, the umbilicus is relatively small. Specimens found in direct association with that form have even larger umbilici, and they are referred to *M. oweni* (Hall). The proportions of *M.? mitchelli* Miller are close to those of *M. rowleyi*, but in that species the sides of the ventral lobes of the sutures are not so nearly parallel. The holotypes of *M. pfefferae* (Miller & Werner) and *M. eshbaughi* (Miller, Downs, & Youngquist) seem to be considerably narrower, but their conchs were crushed during preservation (Text-fig. 4B).

Occurrence.—Some of the specimens on which this species is based were secured over 60 years ago, and they are the result of a lifetime of diligent search. In 1934 the senior author discussed them with the collector, R. R. Rowley, then an octogenarian, who was certain that all the types came from the lower Burlington in the environs of Louisiana, a remembrance that is borne out by the original labels. Rowley stated that the yellow chalcedony specimen, mentioned above, came from the float, but that the other individuals had been found *in situ*. Keyes & Rowley listed goniatites from the upper Burlington at the same locality, a citation that can not be verified.

Repository.—University Illinois X-1480 (holotype), X-1481 (paratype), X-1482–1484 (figured specimens). The small (15 mm.) subglobular individual mentioned by Miller (1935, p. 434) has apparently been misplaced.

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—— & COLLINSON, CHARLES, 1951, Lower Mississippian ammonoids of Missouri: Jour. Paleontology, v. 25, p. 454–487, pls. 68–71.

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ROWLEY, R. R., 1908, The geology of Pike County: Missouri Bur. Geology Mines, ser. 2, v. 8, 122 p., 20 pls.

SMITH, J. P., 1903, Carboniferous ammonoids of America: U. S. Geol. Survey, Mon. 42, 211 p., 29 pls.

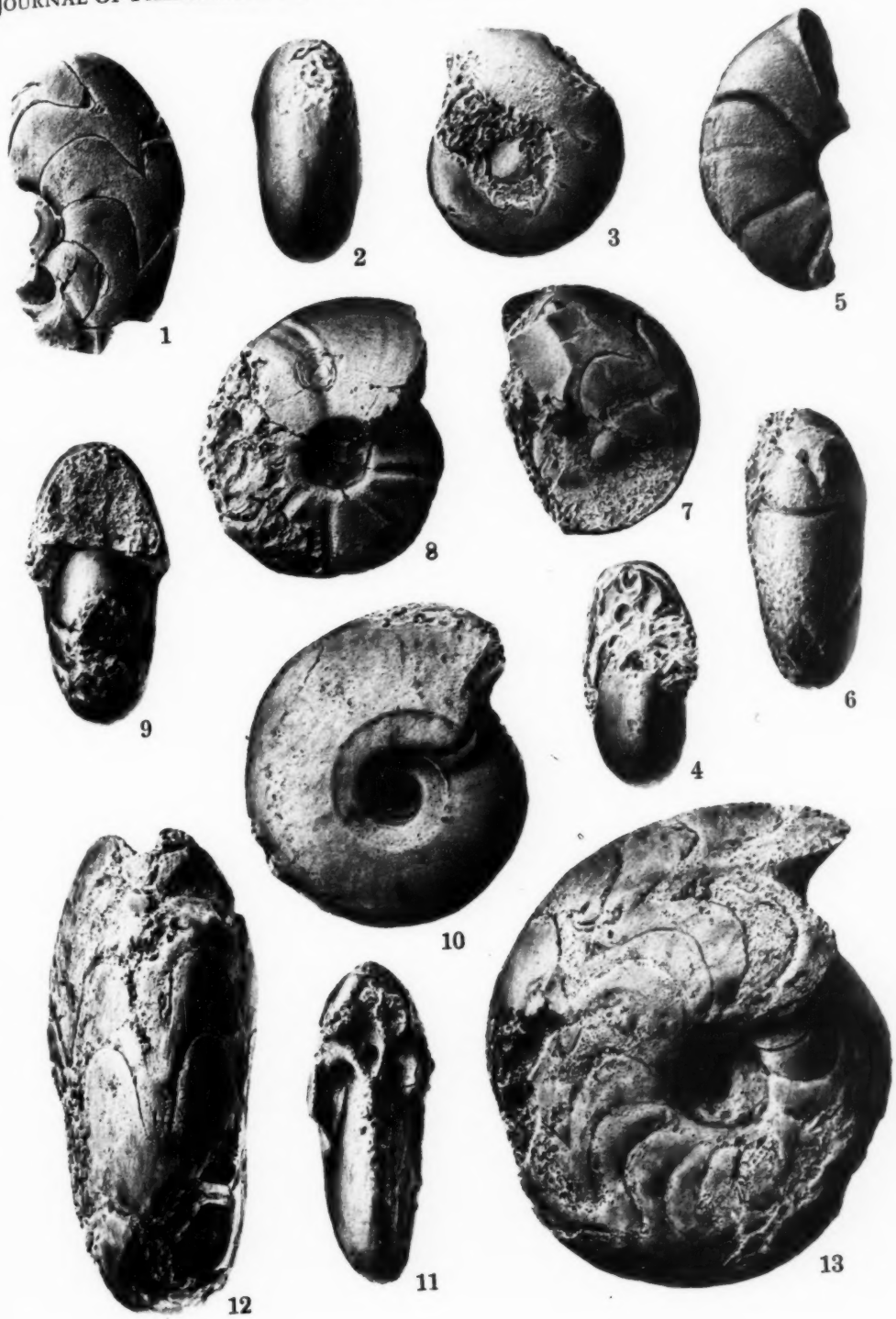
EXPLANATION OF PLATE 35

The photographs were retouched by Howard E. Webster.

FIGS. *1–9*—*Muensteroceras rowleyi* M. & F., n. sp. Holotype and four paratypes from lower Burlington Formation at Louisiana, Missouri, ×1. All from Rowley Collection (Univ. Ill.). *1*, Part of holotype; *2–4* represent a single specimen, as do *5,6* and *8,9*.

10,11—*Muensteroceras* sp. From same horizon, locality, and collection as preceding, ×1½.

12,13—*Muensteroceras? mitchelli* Miller. Holotype (Univ. Mo., 6694) from lower Burlington Formation, Cooper County, Missouri, ×1.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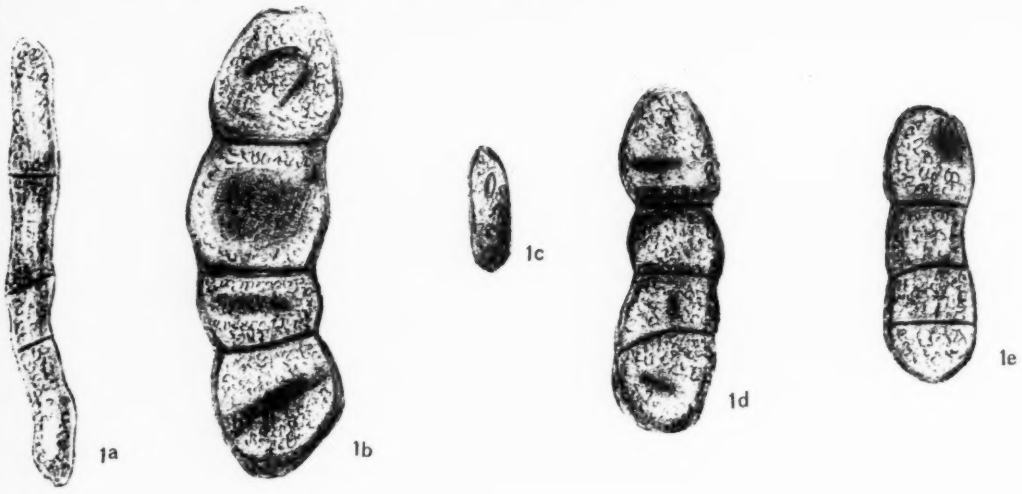
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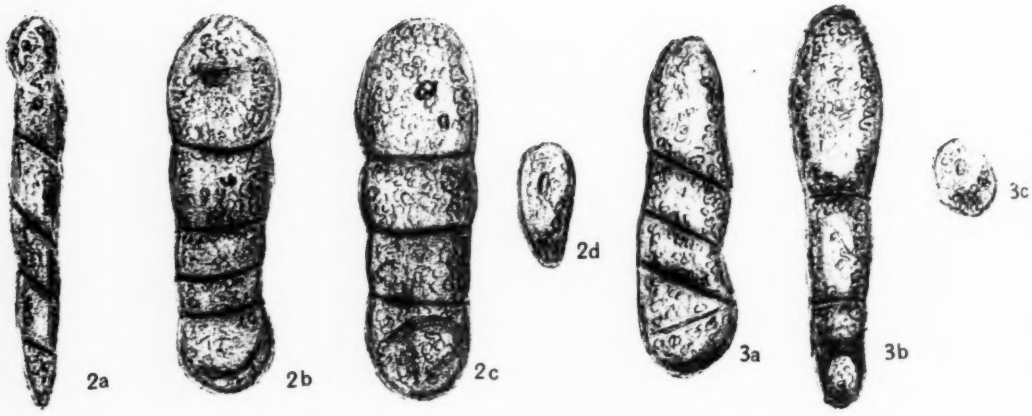
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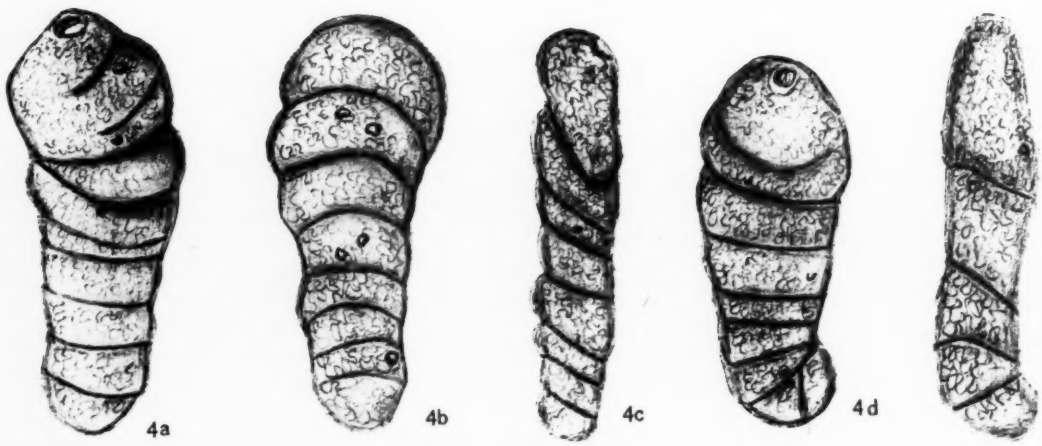
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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 275–285, PLS. 36–38, 1 TEXT-FIG., MARCH 1958

LOWER CRETACEOUS FORAMINIFERA OF THE BLACK HILLS AREA

HERBERT SKOLNICK
Western Gulf Company, Ventura, California

ABSTRACT—The classification of the Skull Creek shale, the Newcastle sandstone and the Mowry shale of the Black Hills region has been considered recently and, as the result of paleontological studies, these stratigraphic units are now assigned to the Lower Cretaceous.

These Lower Cretaceous rocks contain 15 species of arenaceous Foraminifera of which *Ammobaculites altilis, A. culmula, A. imbricatus, A. impolitus, A. urniformis, Ammobaculoides minuens, Haplophragmoides regularis, H. paralius*, and *Trochammina phaseolus* are new. This Black Hills assemblage is similar in part to microfauna of Fredericksburg and Washita age found in some of the rocks of Kansas, Oklahoma, and Texas. The Black Hills Foraminifera are the type found today in near-shore, brackish, shallow water lagoonal deposits.

INTRODUCTION

ASIDE from a brief statement by Crowley (1951) mentioning the occurrence of Foraminifera in the Skull Creek shale and in the shale beds of the Newcastle sandstone, no work with the Lower Cretaceous Foraminifera in the Black Hills area has been reported to date.

All of the Foraminifera discussed in this paper were collected by the author from the following sections in the Skull Creek shale, the Newcastle sandstone and the Mowry shale: Section 1 of the Skull Creek shale along U. S. Highway 85, 0.75 to 1.75 miles south of Belle Fourche, Butte County, South Dakota, sec. 15 and 22, T. 8 N., R. 2 E.; Section 2 of the Skull Creek shale and the Newcastle sandstone 7 miles northeast of New Haven, Crook County, Wyoming, NW¼ sec. 17, T. 56 N., R. 66 W.; Section 3 of the Skull Creek shale, Newcastle sandstone and basal Mowry shale 0.1 mile north of Rapid City, Pennington County, South Dakota, SW¼ NW¼ sec. 36, T. 2 N., R. 7 E.; Section 4 of the Skull Creek shale and the Newcastle sandstone along section road 7.5 to 8.0 miles northeast of New Haven, Crook County, Wyoming, sec. 11 and 14, T. 56 N., R. 66 W.

COLLECTING ZONES

The following are the faunal zones from which Foraminifera were recovered:

Section 1

Faunal zone 1. 3 feet above the base of the Skull Creek shale.
Faunal zone 2. 120 feet above the base of the Skull Creek shale.
Faunal zone 3. 157 feet above the base of the Skull Creek shale.
Faunal zone 4. 202 feet above the base of the Skull Creek shale.

Section 2

Faunal zone 1. 174 feet above the base of the Skull Creek shale.
Faunal zone 2. 175 feet above the base of the Skull Creek shale.
Faunal zone 3. 187.9 feet above the base of the Skull Creek shale.

EXPLANATION OF PLATE 36

FIG. 1—*Ammobaculites altilis* Skolnick, n. sp. a, Edge view; b, side view; c, apertural view; all ×53 of holotype SUI No. 5621; d, side view of paratype SUI No. 5622, ×42; and e, side view of paratype SUI No. 5623, ×45.

2—*Ammobaculites impolitus* Skolnick, n. sp, a, Edge view; b, side view; d, apertural view; all ×49 of holotype SUI No. 5633; and c, side view of paratype SUI No. 5634, ×47.

3—*Ammobaculites obliquus* Loeblich & Tappan. a, Side view ×93 of hypotype SUI No. 5635; b, edge view; c, apertural view; and d, side view; all of hypotype SUI No. 5636, ×89.

4—*Ammobaculites imbricatus* Skolnick, n. sp. a, Side view; b, side view; c, edge view; all ×48 of holotype SUI No. 5630; d, side view of paratype SUI No. 5631, ×45.

Section 3

Faunal zone 1. 132.1 feet above the base of the Skull Creek shale.
Faunal zone 2. 142.1 feet above the base of the Skull Creek shale.
Faunal zone 3. 152.5 feet above the base of the Skull Creek shale.
Faunal zone 4. 172 feet above the base of the Skull Creek shale.
Faunal zone 5. 177 feet above the base of the Skull Creek shale, immediately below the basal Newcastle sandstone.
Faunal zone 6. Lower Mowry shale 203 feet above base of Skull Creek shale.

Section 4

Faunal zone 1. 19 feet above the base of the Skull Creek shale.
Faunal zone 2. 110 feet above the base of the Skull Creek shale.
Faunal zone 3. 157.6 feet above the base of the Skull Creek shale.
Faunal zone 4. 184.4 feet above the base of the Skull Creek shale, in basal shale of the Newcastle sandstone.

Section 13

Faunal zone 1. 1 to 3 feet above the base of the Mowry shale.

STRATIGRAPHY

The sedimentary rocks studied during this investigation occupy most of that part of the Cretaceous section originally defined by Gilbert (1896) as the Graneros formation, a unit composed of laminated argillaceous gray shales 200 to 210 feet thick containing little calcaerous or sandy material and occurring at the base of the Benton group in the Arkansas Valley region of Colorado. This formation was named for Graneros Creek in Pueblo County, southern Colorado and has subsequently been divided by others into the Skull Creek shale, the Newcastle sandstone, the Nefsy shale and the Mowry shale.

LITHOLOGY

Skull Creek Shale.—The Skull Creek shale ranges in thickness from 185 to 267 feet, is dark bluish-gray, fissile, and locally contains thin silty zones in the upper and basal portions. Several thin zones of bentonitic shale occur in the section but are difficult to distinguish as their boundaries are indistinct because of the lithologic similarity to the main shale body.

Calcareous cone-in-cone masses were observed in every section examined. Initially the greater resistance of these masses to weathering gives the observer the impression that these are transported boulders enclosed in marine shales, but with continued exposure these masses disintegrate into buff, splintery fragments, resembling a litter of wood chips.

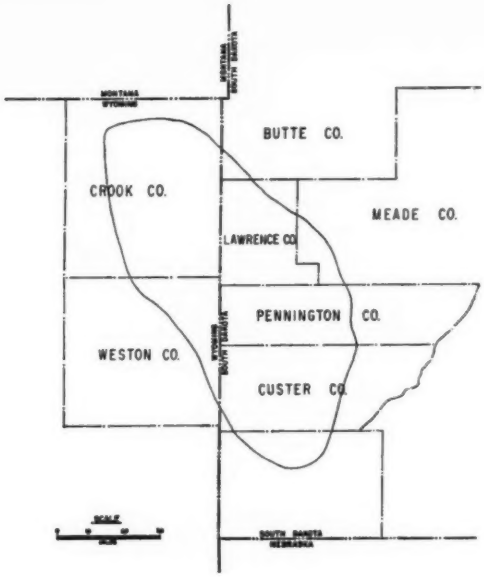
The Skull Creek shale apparently is conformable with the Fall River sandstone below and the Newcastle sandstone above. However, in the absence of the latter sandstone, the Skull Creek shale grades upward into the Mowry shale and this interval of Skull Creek shale, occupying the same stratigraphic position of the Newcastle sandstone, was found to contain neither lithologic nor fossil horizons by which the observer can orient himself in the section.

Valleys characteristically form in the Skull Creek shale except where a capping of Newcastle is sufficiently resistant to form a ridge. The nature of the shales in the valleys is obscured by the soil cover and vegetation, but there are exposures in the banks and ditches of section roads and highways which trend across the strike of the unit. Unlike the valley areas, the Skull Creek shale in the ridges capped by the Newcastle sandstone, is usually devoid of vegetation, and when viewed at a distance resembles cinders.

Newcastle Sandstone.—The Newcastle sandstone is a lenticular unit that ranges in thickness from a thin edge to 95 feet and consists of interfingering sandstones, siltstones, and shales. Most of the unit is composed of fine-grained, well-sorted sandstones ranging in color from dark brownish-gray to yellowish-orange. Locally both current and oscillation ripple marks as well as crossbedding are present. Beds of yellow and brown bentonite and bone coal occur in the sections at Upton, Osage, and Newcastle.

Fusain, imparting a dark color to the rocks, is locally a common constituent, and with the exception of the sections in the vicinity of New Haven, Wyoming is present in all the exposures on the northern and western flanks in the Black Hills.

The Newcastle sandstone is exposed in a series of discontinuous ridges around the periphery of the Black Hills with gaps of the magnitude of 40 miles between exposures. Ridges up to 175 feet in height mark the occurrence of the thicker sandstone zones



INDEX MAP
SHOWING GENERALIZED LIMITS OF EXPOSURE
OF LOWER CRETACEOUS ROCKS UNDER DISCUSSION

TEXT-FIG. *1*

but lower hills are in the areas where the sandy facies is poorly developed. In the absence of the sandstone, valley flats are developed in the non-resistant Skull Creek shale. In those areas where the Newcastle sandstone is present it apparently conformably overlies the Skull Creek shale and in turn is conformably overlain by the Mowry shale. Total thickness differed from exposure to exposure, ranging from 94 feet at Newcastle to 9.8 feet west of Belle Fourche. As a result, in many areas along the strike of the rocks, Skull Creek beds of one section are contemporaneous with Newcastle beds of another section and in the absence of the sandstone the time interval normally represented by the Newcastle is occupied by the Skull Creek. It is this phenomenon which has led the writer to consider the Newcastle as a lenticular unit whose individual lenses are enclosed in the Skull Creek shale, genetically related to the Skull Creek but of subordinate rank.

In contrast to the Skull Creek shale, the sandy texture of the soil derived from the Newcastle sandstone permits the growth of pine and it is common to find a pine crested isolated ridge on a grass covered valley flat of the Skull Creek shale.

Mowry Shale.—The Mowry shale, ranging in thickness from 200 to 250 feet, is dominantly siliceous with local occurrences of argillaceous beds in the basal portion. The tougher, more resistant material is characteristically exposed as light-gray, elongate, pine covered hills. The basal, less resistant portion when present, forms low areas in front of the hills formed by the more resistant Mowry.

The dark brownish-gray lower, non-resistant portion of the Mowry shale, the Nefsy shale of Collier (1922), is plastic when wet and is absent from many parts of the section. The upper siliceous portion contains fish teeth, scales and bones.

DEPOSITIONAL ENVIRONMENT

Skull Creek Shale.—The thin-bedded, extremely fine-grained nature of the Skull Creek shale and the lack of evidence of scour action indicates deposition of fine-grained argillaceous muds in quiet water en-

vironments over a wide area. The sediments were derived probably in part from a low lying land mass roughly occupying the area of the central Black Hills. The presence of shallow water, near shore lagoonal assemblages of Foraminifera indicates that deposition occurred in bodies of partly landlocked shallow water, near shore environments. The local thin beds of bentonite indicate that volcanic ash was deposited concurrently with argillaceous muds.

Newcastle Sandstone.—Collier (1922), Dobbin (1947) and Summerford (1950) have noted in detail the many features of the Newcastle sandstone which they consider indicative of shallow water, near shore origin. Crowley (1951, p. 86) mentioned finding cassiterite, tourmaline, and gold in samples of the Fall River and Newcastle sandstones from the west flank of the Black Hills. He considered that these may have originated from the pre-Cambrian rocks of the Keystone area, South Dakota either directly from the lode or as a placer. The interfingering of sandstone, siltstones, shales and local deposits of bone coal indicate a migrating shoreline with shifting longshore currents depositing sands, silts, and muds and resulting in beach and bar deposits. The presence of lagoonal types of Foraminifera locally in some of the shale beds of the Newcastle indicate that aside from conditions resulting locally in sand deposition the environmental regimen was similar to those in the Skull Creek time. It has been reported (Skolnick, 1952) that most of the fusain observed in the Newcastle was of char origin, most likely produced in forest fires on the land area and that concentrations such as occur in the Newcastle originated on the seaward beaches of shifting offshore bars.

Mowry Shale.—The argillaceous thin-bedded character of the basal beds of the Mowry shale indicates the continuation of the depositional environment existing in Skull Creek time. However, the siliceous character of the upper shale and its fish fauna marks a change in environmental conditions which were unfavorable for Foraminifera, a change possibly brought about by deepening of the area of deposition.

COMPOSITION OF FAUNA

The fauna is very unusual in that it is entirely arenaceous, thirteen of the species belonging to the family Lituolidae and two being members of the family Trochamminidae. Very few individuals were recovered after sample processing and occurrences were sporadic. *Ammobaculites imbricatus* and *Ammobaculites impolitus* are the most frequently encountered in the assemblage and only *Ammobaculites subcretaceus* is present in all of the lithic units under discussion. *Ammobaculites euides* Loeblich & Tappan, *A. obliquus* L. & T., *A. torosus* L. & T., *A. subcretaceus* Cushman & Alexander, *Ammobaculoides whitneyi* C. & A., and *Trochammina depressa* Lozo present in the Black Hills rocks have been reported from the Lower Cretaceous rocks of Kansas, Oklahoma, and Texas.

PALEOECOLOGY

Work by Norton (1930), Natland (1933), Phleger (1942), and Phleger & Parker (1951) indicated that temperature and not depth is the most important controlling factor

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EXPLANATION OF PLATE 37

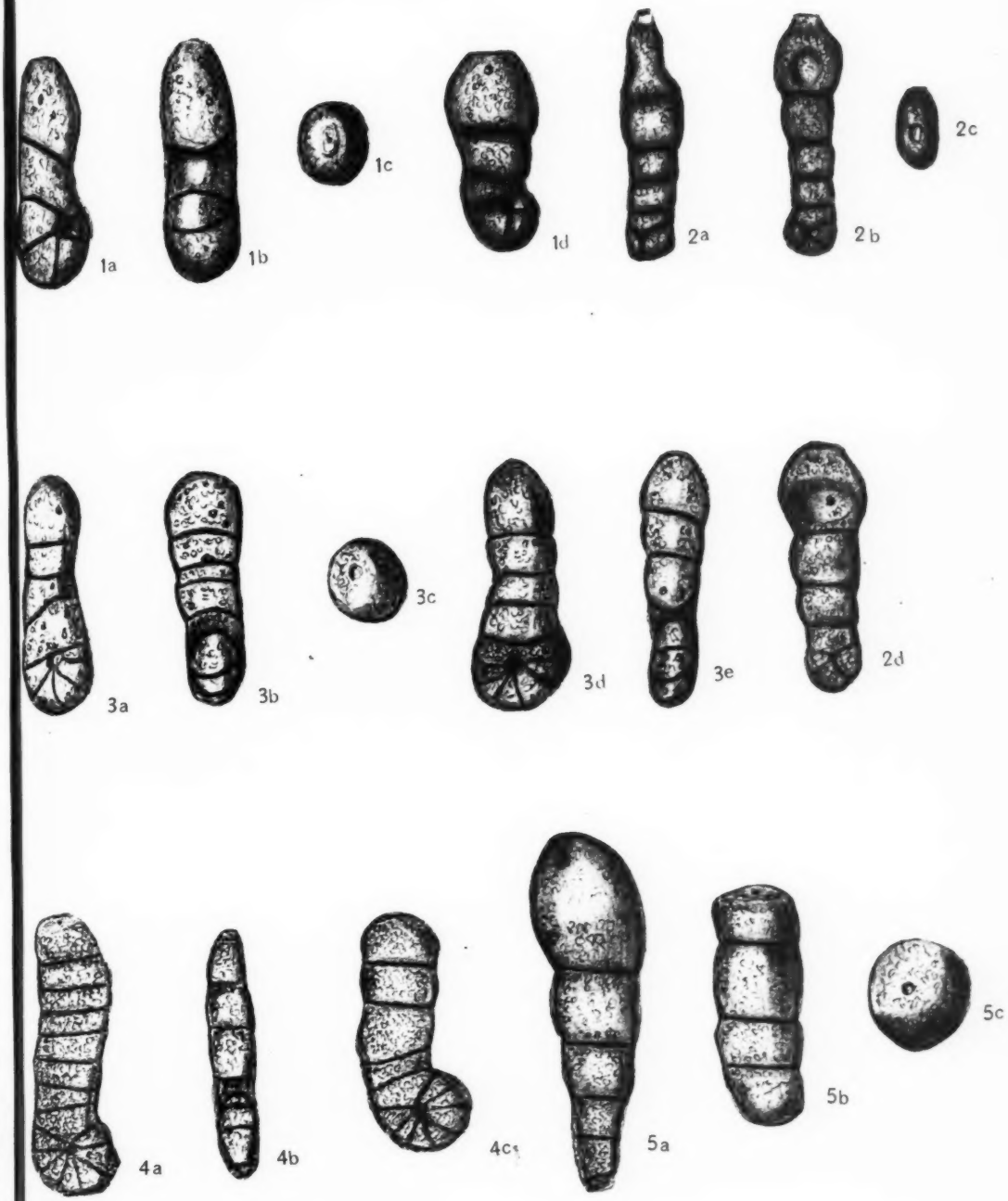
FIG. *1*—*Ammobaculites torosus* Loeblich & Tappan. a, Side view; b, edge view; c, apertural view; all ×43 of hypotype SUI No. 5641; and d, side view of hypotype SUI No. 5642, ×44.

2—*Ammobaculites culmula* Skolnick, n. sp. a, Edge view; b, side view; and c, apertural view; all ×46 of holotype SUI No. 5624; and d, side view of paratype SUI No. 5625, ×49.

3—*Ammobaculites urniformis* Skolnick, n. sp. a, Side view; b, edge view; and c, apertural view; all ×51 of holotype SUI No. 5643; d, side view; and e, edge view of paratype SUI No. 5644, ×44.

4—*Ammobaculites subcretaceus* Cushman & Alexander. a, Side view and b, edge view ×89 of hypotype SUI No. 5637; and c, side view of hypotype SUI No. 5638, ×43.

5—*Ammobaculites euides* Loeblich & Tappan. a, Side view and c, apertural view ×53 of hypotype SUI No. 5627; b, side view of hypotype SUI No. 5628, ×42.


1a
1b
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5a
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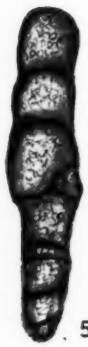
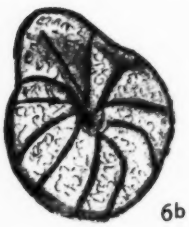
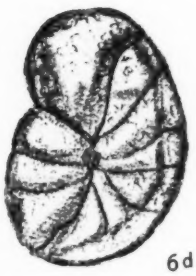

5c

5d

6a


6b

6c


6d

governing the distribution of Foraminifera.

However, some workers have indicated that some assemblages are controlled by salinity. Lowman (1949) found that *Ammobaculites* is the dominant genus in weakly brackish environments, and that *Haplophragmoides* and *Trochammina* are very numerous in salt marshes on the Pacific coast. Phleger & Walton (1950) found that *Trochammina* and *Ammobaculites* in harbors and bays can tolerate wide changes in salinity. As indicated by Ellison (1951), *Ammobaculites*, *Haplophragmoides*, and *Trochammina* occur together in brackish-lagoonal, transitional-brackish, to open sea environments.

Phleger (1954) reported the numerical domination by several species of *Ammobaculites* of the entire foraminiferal assemblage from sediments of Mississippi Sound in Mississippi and Alabama and attributed this phenomenon to the presence of an offshore island chain acting as a barrier to prevent invasion of the sound by marine open-gulf waters in an area where runoff exceeds evaporation. Bandy (1956, p. 182,184) found that in Mobile Bay, Alabama assemblages *Ammobaculites* was able to tolerate wide ranges in salinity and was therefore restricted to harbors and bays, areas avoided by species with a more critical tolerance of salinity. The completely arenaceous character of the Black Hills assemblage, the generic dominance by species of *Ammobaculites*, and the extreme rarity of a megafauna indicate a rigorous environment during deposition of these lithic units, an environment such as that occurring today in lagoonal areas along the Gulf Coast of Mississippi and Alabama.

AGE AND CORRELATION

As the result of work by Reeside (1944) and Crowley (1951) the Skull Creek shale and the Newcastle sandstone, respectively, have been shown to be of Lower Cretaceous age. Cobban and Reeside (1951) have reported finding Lower Cretaceous ammonites in the Mowry shale of the western flanks of the Black Hills and from the Mowry equivalents of Colorado, Montana, and Wyoming which indicate the age of the Mowry ranges from the top of Middle to Upper Albian.

The writer concludes that the microfauna from the shales of the Black Hills area is similar to the assemblages of the Walnut, Kiowa, and Kiamichi formations, Fredericksburg age, of Kansas, Oklahoma, and Texas. Therefore, the Skull Creek shale, the Newcastle sandstone, and the lower portion of the Mowry shale are Fredericksburg in age, middle Lower Cretaceous, Lower and Middle Albian of Europe.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Mr. A. J. Crowley, Continental Oil Company, for suggesting the problem and pointing out collecting localities; to Professor A. C. Tester and Professor A. K. Miller who offered advice and encouragement during the course of the study at the State University of Iowa and to Professor O. L. Bandy, University of Southern California-for helpful suggestions regarding the illustra,

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EXPLANATION OF PLATE 38

FIG. *1*—*Haplophragmoides regularis* Skolnick, n. sp. a, Side view; b, edge view; all ×48 of holotype SUI No. 5654; c, side view of paratype SUI No. 5655, ×50.

2—*Haplophragmoides paralius* Skolnick, n. sp. a, Side view; and b, edge view of holotype SUI No. 5652, both ×47.

3—*Trochammina depressa* Lozo. a, Ventral side; b, dorsal side; c, edge view of hypotype SUI No. 5656, all ×40.

4—*Ammobaculoides whitneyi* Cushman & Alexander. a, Side view; b, apertural view; c, edge view of hypotype SUI No. 5647, all ×45.

5—*Ammobaculoides minuens* Skolnick, n. sp. a, Side view; c, edge view; and d, apertural view of holotype SUI No. 5645; b, side view of paratype SUI No. 5646, all ×51.

6—*Trochammina phaseolus* Skolnick, n. sp. a, Ventral view; b, dorsal view; and c, edge view ×53 of holotype SUI No. 5658; d, side view of paratype SUI No. 5659, ×48.

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SYSTEMATIC DESCRIPTIONS

Family LITUOLIDAE
Subfamily HAPLOPHRAGMIINAE
Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES ALTILIS Skolnick, n. sp.
Pl. 36, figs. 1a–e

The test is free, slightly arcuate and flattened. The early portion is involutely coiled and obscure with a rounded periphery and from four to five chambers visible in the immersion medium. The later portion of the test is uniserial with three to four chambers which gradually increase in height. These chambers are narrow at the base and top but wider in the central portion, resulting in a "pinch and swell" outline. The sutures are depressed and oblique in early portion but straight in the later portion. The wall is finely arenaceous with much cement and the aperture is terminal and elliptical at the top of the last formed chamber.

The holotype is 1.28 mm. long and ranges in width from 0.35 mm. to 0.48 mm. and in thickness from 0.11 mm. to 0.16 mm. The greatest width of the coil is 0.40 mm. and the greatest thickness is 0.11 mm. The other figured specimens range in length from 0.80 mm. to 1.15 mm.

Remarks.—This species is larger than *Ammobaculites obscurus* Loeblich from the Upper Cretaceous Pepper shale of Texas, is more compressed, has a smaller, less distinct coil, is more arcuate in edge view, has a more scalloped periphery in the rectilinear portion and has higher chambers which become narrower with later growth.

Occurrence.—This species is found in the Skull Creek shale at Section 4, zones 2 and 3; Section 3, zone 2; and Section 1, zone 4.

Figured Specimens.—Holotype, State University of Iowa 5621, paratypes, State University of Iowa 5622, 5623.

AMMOBACULITES CULMULA Skolnick, n. sp.
Pl. 37, figs. 2a–d

The test is free and elongate with the early portion involutely coiled and umbilicate and consisting of from three to four visible chambers. The later portion is uniserial and cylindrical consisting of from four to five chambers which gradually increase in height and width. The terminal chamber is typically deflated. The sutures are straight and somewhat depressed in the uniserial portion but obscure in the coiled portion. The wall is finely arenaceous. The aperture is terminal and round at the end of a short neck at the top of the last formed chamber.

The holotype is 0.78 mm. long and ranges in width from 0.18 mm. to 0.14 mm. and is 0.11 mm. thick. The greatest diameter of the coil is 0.12 mm. The length of the other figured specimen is 0.73 mm.

Remarks.—This species bears little resemblance to any previously established species. The only species which remotely resembles the present form is *Ammobaculites inconspicua* Cushman & Waters from the Pennsylvanian Canyon division of Texas. The present species is larger, has a smaller coil, rectilinear chambers which increase more rapidly in height with later growth, deflation of the last chamber and a shorter terminal neck.

Occurrence.—This species is found in the lower part of the Skull Creek shale at Section 1, zones 1 and 2.

Figured Specimens.—Holotype, State University of Iowa 5624, paratype State University of Iowa 5625.

AMMOBACULITES EUIDES Loeblich & Tappan, 1949
Pl. 37, figs. 5a–c

Ammobaculites euides LOEBLICH & TAPPAN, 1949, Jour. Washington Acad. Sci., v. 39, p. 90; —— 1949, Jour. Paleont., v. 23, p. 251, pl. 46, figs. 8a,b.

The length of the microspheric individual is 0.99 mm. and it ranges in width from 0.33 mm. to 0.16 mm. The greatest thickness is 0.33 mm. The length of the other figured specimen is 0.83 mm. Unfigured hypotypes range in length from 0.62 mm. to 0.81.

Remarks.—This species despite its well cemented appearance is fragile. No complete adult specimens were found in the shale. Apparently, lines of weakness exist along sutures, for most of the specimens were broken in this manner. This species has been reported from the Walnut clay and the Kiowa shale, Fredericksburg and Washita in age respectively.

Occurrence.—This species was found at

only one locality in the Skull Creek shale; Section 3, zone 2.

Figured Specimens.—Hypotypes, State University of Iowa 5627, 5628.

AMMOBACULITES IMBRICATUS Skolnick, n. sp.
Pl. 36, figs. 4a–d

The test is free, elongate, slightly arcuate, and oval in cross section. The early portion is involutely coiled and obscure with from five to six narrow chambers visible in immersion medium. The later portion is uniserial with from four to seven imbricate chambers which gradually increase in width with little change in height. The last two uniserial chambers have a keel developed around the periphery. The sutures are distinct, curved and depressed in the uniserial portion but obscure in the coiled portion. The wall is arenaceous with much cement and the aperture is terminal and round at the top of the last formed chamber.

Remarks.—This species resembles *Ammobaculites nummus* Garrett which has been reported from the Oligocene Hackberry shale by Garrett (1938). However, the Lower Cretaceous species is smaller and does not develop the keeled periphery around the chambers until its later growth. The older species may be an ancestral form from which *Ammobaculites nummus* Garrett developed.

The holotype is 1.16 mm. long. The greatest width of the uniserial portion is 0.49 mm. and the greatest thickness is 0.33 mm. The greatest width of the coiled portion is 0.43 mm. and the greatest thickness is 0.11 mm. The length of the figured paratype is 1.09 mm.

Occurrence.—This species is found throughout most of the Skull Creek shale, occurring at Section 1, zones 1, 2, and 4; Section 2, zone 3; Section 3, zones 2, 3 and 5.

Figured Specimens.—Holotype, State University of Iowa 5630, paratypes State University of Iowa 5631.

AMMOBACULITES IMPOLITUS Skolnick, n. sp.
Pl. 36, figs. 2a–d

The test is free, elogate and flattened. The early portion of the test is involutely coiled but obscure, with three to four chambers visible on immersion. The later portion is uniserial with three to four imbricate chambers which gradually increase in height with little change in width. The last formed chamber is more than three times the height of the first uniserial chamber. The sutures are obscure in the coiled portion and curved and depressed in the uniserial portion. The wall is arenaceous with a very rough appearance and the aperture is terminal and round at the top of the last formed chamber.

The holotype is 1.07 mm. long, ranges in width from 0.28 mm. to 0.43 mm. and measures 0.18 mm. in the thickest part. The greatest width of the coil is 0.33 mm. and the greatest thickness is 0.083 mm. The figured paratype is 1.07 mm. long and the unfigured specimens range in length from 0.68 mm. to 1.04 mm.

Remarks.—This species is similar to *Ammobaculites parvispira* ten Dam from the Lower Cretaceous, Albian of the extreme eastern part of the Netherlands. However, *A. impolitus* is larger, the uniserial chambers increase more rapidly in size, the cross section is flat, and the exterior is rougher with much cement.

Occurrence.—This species is found throughout the Skull Creek shale and has the widest geographical distribution of any of the Foraminifera indigenous to the Skull Creek shale. It is found at Section 1, zones 2 and 4; Section 2, zones 1 and 3; Section 3, zones 3 and 5; and Section 4, zones 1, 2, and 4.

This species is also found at Section 3, zone 6 in the basal shale of the Newcastle sandstone.

Figured Specimens.—Holotype, State University of Iowa 5633, paratype, State University of Iowa 5634.

AMMOBACULITES OBLIQUUS Loeblich & Tappan, 1949
Pl. 36, figs. 3a–d

Ammobaculites obliquus LOEBLICH & TAPPAN, 1949, Jour. Paleont., v. 23, p. 250, pl. 46, figs. 4a–5.

The length of the larger figured hypotype is 0.55 mm. and the smaller is 0.51 mm. The diameter of the coiled portion of the larger hypotype ranges from 0.10 mm. to 0.14 mm. and the width of its uniserial portion ranges from 0.12 mm. to 0.15 mm. The uniserial

part is 0.10 mm. thick and the coil is 0.06 mm. thick.

Remarks.—This species has been reported from the Kiowa shale of Kansas and the Walnut clay of Texas; formations of Fredericksburg and Washita age respectively.

Occurrence.—This species was found in the Skull Creek shale at Section 3, zone 2.

Figured Specimens.—Hypotypes, State University of Iowa 5635, 5636.

AMMOBACULITES SUBCRETACEUS
Cushman & Alexander, 1930
Pl. 37, figs. 4a–c

Ammobaculites subcretacea CUSHMAN & ALEXANDER, 1930, Contr. Cushman Lab. Foram. Res., v. 6, p. 6, pl. 2, figs. 9–10; ALBRITTON, 1937, Jour. Paleont., v. 11, p. 20, pl. 4, figs. 3–4.

Ammobaculites subcretaceus LOZO, 1944, The Am. Midland Naturalist, v. 31, p. 538, pl. 4, figs. 2–3; LOEBLICH & TAPPAN, 1949, Jour. Paleont., v. 23, p. 251, pl. 46, figs. 9–13.

The smaller hypotype is 0.83 mm. long. The coil ranges in diameter from 0.26 mm. to 0.31 mm. and is 0.13 mm. thick. The uniserial portion is 0.29 mm. wide and ranges in thickness from 0.10 mm. to 0.16 mm. The larger figured hypotype is 1.37 mm. long. Other specimens range in length from 0.41 mm. to 0.84 mm.

Remarks.—This species has been reported from the Kiamichi, Goodland and Walnut formations of Texas and also from the Walnut of Texas and Oklahoma.

Occurrence.—This species is the only one found in all three of the Lower Cretaceous formations studied in this report. It occurs in the Skull Creek shale at Section 1, zone 1; Section 2, zones 1 and 6; Section 3, zones 2 and 4 and in the basal shale of the Newcastle sandstone, Section 3, zone 6.

Figured Specimens.—Hypotypes, State University of Iowa 5637, 5638 and unfigured hypotypes 5639 and 5640.

AMMOBACULITES TOROSUS Loeblich & Tappan, 1949
Pl. 37, figs. 1a–d

Ammobaculites torosus LOEBLICH & TAPPAN, 1949, Jour. Paleont., v. 23, p. 251, pl. 46, figs. 6a–7.

The larger figured hypotype is 0.79 mm. long. The coiled portion at its maximum diameter measures 0.39 mm. and is 0.24 mm. at its maximum thickness. The greatest width of the uniserial portion is 0.23 mm. and its greatest thickness is 0.23 mm. The smaller figured hypotype is 0.66 mm. long.

Remarks.—This species resembles *Ammobaculites linea* Lalicker from the Middle Jurassic Sawtooth formation but the present form is larger, more compressed, with more distinct sutures, finer arenaceous wall and lacks the short terminal neck.

This species has been reported from the Walnut clay of Texas, Fredericksburg in age. Only a few specimens of this species were found in the Skull Creek shale.

Occurrence.—This species was found only at Section 3, zone 2 of the Skull Creek shale.

Figured Specimens.—Hypotypes, State University of Iowa 5641–5642.

AMMOBACULITES URNIFORMIS Skolnick, n. sp.
Pl. 37, figs. 3a–e

The test is free and elongate. The early portion is involutely coiled and centrally umbilicate with a rounded periphery and five visible chambers. The later portion of the test is uniserial with from three to four chambers, the first two of which increase in height but decrease slightly in width. The last formed chamber increases both in height and width. All of the chambers gradually increase in thickness so that in edge view the test is wedge-shaped. The sutures are obscure in the coil and both straight and oblique in the uniserial portion. The wall is arenaceous with much cement and the aperture is terminal and round at the top of the last formed chamber.

The holotype is 0.71 mm. long. The coiled portion at its maximum diameter measures 0.31 mm. and is 0.14 mm. at its maximum thickness. The greatest width of the uniserial portion is 0.22 mm. and its greatest thickness is 0.24 mm. The paratype is 0.76 mm. long.

Remarks.—This species resembles *Ammobaculites cobbani* Loeblich & Tappan from the Jurassic type Redwater shale of South Dakota but the present form is smaller, less compressed, with more obscure sutures in the coil, higher and narrower rectilinear chambers and a round aperture.

Like most of the fauna collected from the

Skull Creek shale only a few individuals of the species were found in the washed samples.

Occurrence.—This species was found only at one exposure in the Skull Creek shale; at Section 3, zone 2.

Figured Specimens.—Holotype, State University of Iowa 5643, paratype 5644.

Genus AMMOBACULOIDES Plummer, 1932

AMMOBACULOIDES MINUENS Skolnick, n. sp.

Pl. 38, figs. 5a–d

The test is free, elongate, and oval in cross section. The early portion of the test is involutely coiled and umbilicate with from six to eight chambers. The remainder of the test is biserial and uniserial in that order, and of the succeeding seven chambers, four are in the biserial portion and three are in the uniserial portion. The biserial chambers are inflated with little increase in size. The first uniserial chamber is wedge-shaped and covers the entire width of the test but the remaining two chambers lose this tendency and are more uniform in outline. The sutures in the coiled portion are obscure but are distinct and curved in the biserial portion and distinct, straight or curved and oblique in the uniserial portion. The wall is finely arenaceous and the aperture is terminal and round, at the top of the last formed chamber.

The length of the holotype is 0.88 mm. The coil measures 0.26 mm. at its greatest diameter and 0.11 mm. at its greatest thickness. The greatest width of the biserial portion is 0.26 mm. and its greatest thickness is 0.14 mm. The greatest width of the uniserial portion is 0.31 mm. and the greatest thickness is 0.18 mm. The paratype is 0.93 mm. long.

Remarks.—This species bears no close resemblance to any established species. There is a remote resemblance to *Ammobaculoides gainesvillensis* Loeblich & Tappan from the Lower Cretaceous Denton formation of Texas in that all three growth stages are distinct. However, the present form is larger, less compressed and with the uniserial chambers as wide as the biserial portion of the test.

Occurrence.—This species is found in the following sections of the Skull Creek shale; Section 2, zone 2; and Section 3, zones 3 and 4.

Figured Specimens.—Holotype, State University of Iowa 5645, paratype, State University of Iowa 5646.

AMMOBACULOIDES WHITNEYI (Cushman & Alexander), 1930

Pl. 38, figs. 4a–c

Spiroplectammina whitneyi CUSHMAN & ALEXANDER, 1930, Contr. Cushman Lab. Foram. Res., v. 6, p. 8, pl. 2, figs. 12a–b.

Spiroplectammina cf. *whitneyi* Cushman & Alexander, LOZO, 1944, The Am. Midland Naturalist, v. 31, p. 551.

Ammobaculoides whitneyi (Cushman & Alexander), LOEBLICH & TAPPAN, 1949, Jour. Paleont., v. 23, p. 252, pl. 47, figs. 2a–4.

The hypotype is 0.80 mm. long. The greatest diameter of the coil is 0.16 mm. and the greatest width of the biserial portion is 0.24 mm. The greatest width of the uniserial portion is 0.16 mm. The unfigured hypotypes range in length from 0.51 mm. to 0.64 mm.

Remarks.—This species has been reported from the Kiamichi and Goodland formations as well as the Walnut clay.

Occurrence.—This species is found in the Skull Creek shale at Section 1, zone 4; and Section 3, zone 2.

Figured Specimens.—Hypotype, State University of Iowa 5647.

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES PARALIUS Skolnick, n. sp.

Pl. 38, figs. 2a–b

The test is free, small, involutely coiled, umbilicate, and somewhat biconvex. The periphery is broad and rounded with seven visible chambers which rapidly increase in size. The sutures are distinct, depressed, slightly curved and radiate. The wall is finely arenaceous with much cement, resulting in a smooth finish. The aperture is a low arched slit at the base of the last formed chamber.

The holotype ranges in diameter from 0.43 mm. to 0.49 mm. The greatest thickness is 0.13 mm. The greatest diameter of the unfigured paratype is 0.49 mm.

Remarks.—This species resembles *Haplophragmoides rota* Nauss from the Lower

Cretaceous Lloydmaster shale of Alberta but but the present form is smaller, more compressed, the sutures are more distinct, more depressed and slightly curved, the chambers are lesss numerous and the outline less symmetrical.

Occurrence.—This species was found at one exposure in the Skull Creek shale at Section 4, zone 4.

Figured Specimens.—Holotype, State University of Iowa 5652, unfigured paratypes, State University of Iowa 5651, 5653.

HAPLOPHRAGMOIDES REGULARIS
Skolnick, n. sp.
Pl. 38, figs. 1a–c

The test is free, involutely coiled, umbilicate, and biconvex. The periphery is broad and rounded with six to seven visible chambers which rapidly increase in size in the final whorl. The sutures are distinct, slightly curved and radiate. The wall is finely arenaceous with much cement and the aperture is a low arched slit at the base of the last formed chamber.

The holotype ranges in diameter from 0.35 mm. to 0.48 mm. and ranges in thickness from 0.16 mm. to 0.24 mm. The greatest diameter of the paratype is 0.38 mm.

Remarks.—This species resembles *Haplophragmoides linki* Nauss from the Lower Cretaceous Lloydmaster shale of Alberta but the present form is larger, the umbilical area is smaller and chamber width increases more rapidly.

Occurrence.—This species occurs at only one exposure in the Skull Creek shale at Section 3, zone 2.

Figured Specimens.—Holotype, State University of Iowa 5654, paratype, State University of Iowa 5655.

Family TROCHAMMINIDAE
Subfamily TROCHAMMININAE
Genus TROCHAMMINA Parker & Jones, 1859
TROCHAMMINA DEPRESSA Lozo, 1944
Pl. 38, figs. 3a–c

Trochammina depressa Lozo, 1944, The Am. Midland Naturalist, v. 31, p. 552, pl. 2, figs. 4a,b; LOEBLICH & TAPPAN, 1949, Jour. Paleont., v. 23, p. 256, pl. 49, figs. 1a–c.

The figured hypotype ranges in diameter from 0.43 mm. to 0.58 mm. The greatest thickness is 0.10 mm. Unfigured hypotypes range in size from 0.32 mm. to 0.55 mm.

Remarks.—This species is the only one which can be seen with the aid of a hand lens since it characteristically occurs along bedding planes as white specks against a gray background. It has been reported from the Goodland and Kiamichi formations of Texas and the Walnut of Oklahoma. These lithic units are all Fredericksburg in age.

Occurrence.—This species is found in the lower portion of the Mowry shale in Section 2, zone 6.

Figured Specimen.—Hypotype, State University of Iowa 5656.

TROCHAMMINA PHASEOLUS
Skolnick, n. sp.
Pl. 38, figs. 6a–d

The test is free, trochoid, and slightly concavo-convex. The periphery is broad and rounded with ten narrow chambers visible on the ventral side and thirteen to fifteen on the dorsal side which gradually increase in size. The sutures are distinct and curved on the ventral side but obscure dorsally. The periphery is thickened in the last three chambers resulting in a keel which may be caused by partial deflation of these chambers. The wall is finely arenaceous with much cement. The aperture is a low arched slit at the inner margin of the ventral side of the last formed chamber.

The holotype ranges in diameter from 0.46 mm. to 0.56 mm. The greatest thickness is 0.19 mm. The greatest diameter of the larger figured paratype is 0.73 mm. The other paratypes range in size from 0.55 mm. to 0.63 mm.

Remarks.—This species resembles *Trochammina squamata* Jones & Parker, variety *limbata* Chapman but the present form is slightly umbilicate, has more numerous chambers which increase in width slowly and which are collapsed at the periphery.

Occurrence.—This species occurs in the Skull Creek shale at Section 2, zones 2 and 3; and Section 3, zones 4 and 5.

Figured Specimens.—Holotype, State University of Iowa 5658, paratype, State University of Iowa 5659, unfigured paratypes, State University of Iowa 5660 and 5661.

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CENOMANIAN (CRETACEOUS) AMMONITES FROM TRANS-PECOS TEXAS

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ABSTRACT—The occurrence and preservation of an unusual assemblage of Cenomanian ammonites from the northeastern flank of the Davis Mountains indicates that part of them are derived. *Hypoturrilites*, *Ostlingoceras*, *Pseudouhligella*, and *Neopulchellia* are reported for the first time from the Cretaceous of Texas.

INTRODUCTION

AN EXTREMELY interesting group of ammonites was collected from the base of the Boquillas formation in Trans-Pecos Texas by Brundrette (1954). Several things concerning these ammonites are difficult to interpret. Below undoubted Turonian rocks with representatives of the genera *Glebsoceras*, *Fagesia*, *Metoicoceras*, and others, Brundrette collected the individual of *Metoicoceras* illustrated on Plate 40. This species of *Metoicoceras* seems to belong to the same species as the form pictured by Böse (1920, Pl. 12, figs. 1–3), which Jones (1938) included in his *Metoicoceras bösei;* it should indicate a Turonian age for this part of the formation, although Cobban (1953) has described two species of *Metoicoceras* in association with a subspecies of the type species of *Dunveganoceras*, supposedly Upper Cenomanian (Wright, 1956).

Below this single individual of *Metoicoceras* cf. *M. bösei* Jones, at the base of the Boquillas formation, resting on the Buda limestone, Brundrette found the rest of the fossils described in this paper, including two species of *Ostlingoceras*, a species of *Hypoturrilites*, *Neopulchellia brundrettei*, n. sp., *Pseudouhligella elgini*, n. sp., *Utaturiceras?* sp., and *Watinoceras*, n. sp. The latter two forms are poorly preserved and not specifically determinable, although the *Watinoceras* seems to be new. They indicate an Upper Cenomanian age, probably representing the top zone of the Cenomanian, and rightly underlying the *Metoicoceras* cf. *M. bösei* of the next higher horizon.

On the other hand, occurring with these are species of *Ostlingoceras*, *Hypoturrilites*, and *Neopulchellia*, suggesting a zone at or near the top of the Lower Cenomanian. The range and age of *Pseudouhligella*, heretofore uncertain, is better judged by this association than any previous evidence; Arkell, Kummel, and Wright (1957) give only a Cenomanian age for this genus. A very abundant gastropod associated with this fauna is the *Anchura* sp. (Pl. 39), of which there are several well preserved individuals which have not been studied.

Although uppermost Upper Cenomanian and uppermost Lower Cenomanian ammonites occur together, there are some differences in preservation. The individuals of *Anchura*, *Ostlingoceras*, *Hypoturrilites*, *Neopulchellia*, and *Pseudouhligella* are all thoroughly silicified. After silicification they were somewhat eroded or abraded, and some of them show scars (chatter marks?) which have undergone further corrosion. The specimens of *Utaturiceras?* and *Watinoceras* are only slightly silicified (hence less well preserved), but are highly ferruginous. It would appear that the silicified Lower Cenomanian faunule had been derived and redeposited into the Upper Cenomanian base of the Boquillas formation, which contains, in addition, poorly preserved Upper Cenomanian ammonites.

The assemblage is of further interest in that the Lower Cenomanian part represents the youngest Lower Cenomanian ammonites so far described from Texas. East and north of the Davis Mountains there is an unammonitiferous rudistid sequence in the Buda limestone above the beds containing species of *Budaiceras*. The *Neopulchellia brundrettei*, n. sp., faunule overlies this rudistid bearing sequence. The Lower Cenomanian ammonite zonal sequence as now known from Texas is as follows:

Upper Cenomanian	*Acanthoceras* (various species)
	unconformity
	Neopulchellia brundrettei, n. sp.
	Budaiceras (various species; probably more than one zone)
Lower Cenomanian	*Graysonites lozoi-Plesioturrilites bosquense*
	Graysonites adkinsi
	Plesioturrilites brazoense
Upper Albian	*Drakeoceras drakei*

The fauna here described was collected by Brundrette in the summer and fall of 1953. It is from the base of the Boquillas formation, just above and on the contact with the Buda limestone. It was collected from the two draws just north of the first large draw south of the Cherry Ranch road, just north of the east-west fence on the D. Kingston Ranch, NW corner of sec. 33, Block 57, Township 9, Texas and Pacific Railroad Co., Jeff Davis County, Texas; 30° 56′ 20″ N. latitude and 103° 57′ 20″ W. longitude. This is fossil locality 1 on Brundrette's map (1954).

A more restricted assemblage of the same faunule was collected by Grasso from a slump block of the Boquillas formation from along the fence line north of the cattle guard on the Nevill Ranch road, about 15 miles west of Toyah, Reeves County, Texas. *Hypoturrilites* sp., *Anchura* sp., and *Pseudouhligella elgini*, n. sp., are known from this locality.

I wish to thank R. K. DeFord and Jesse Brundrette for providing the fossils herein described. The fossils are deposited in the collections of The University of Texas, Austin, Texas.

Systematic Descriptions

Phylum Mollusca
Class Cephalopoda
Order Ammonoidea
Suborder Lytoceratina Hyatt, 1889
Superfamily Turrilitaceae Meek, 1876
Family Turrilitidae Meek, 1876
Genus Hypoturrilites Dubordieu, 1953

Hypoturrilites, n. sp.

Pl. 39, fig. 32; Text-fig. 1g.

One-half of one volution of an individual, UT 10285, appears to belong to Dubordieu's genus. The individual is sinistral and possesses the three rows of smaller tubercles as in *H. gravesianus* (d'Orbigny), and these tubercles are faintly clavate; the middle and upper rows are spaced slightly farther apart than are the lower and middle rows. The fourth (upper) row of nodes consists of large tubercles with one tubercle for every three to three and a half tubercles in the other (three lower) rows. The large tubercles are more distantly spaced than in *H. gravesianus*. In addition, the Texas species has low costae extending from the spiral suture to the large tubercles (upper row) or to between the large tubercles where these are not present. The lower half of the whorl is not costate, but the base is costate from the lowest row of tubercles to the umbilicus, there being one costa per tubercle. No suture is observable.

Horizon and localities.—Basal Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; probably Lower Cenomanian, collected by Brundrette. A second individual of *Hypoturrilites*, much larger, which may or may not be the same species, was collected by Grasso from a slump block along the fence line north of the cattle-guard on the Nevill Ranch road, 15 miles west of Toyah, Reeves County.

Genus Ostlingoceras Hyatt, 1900

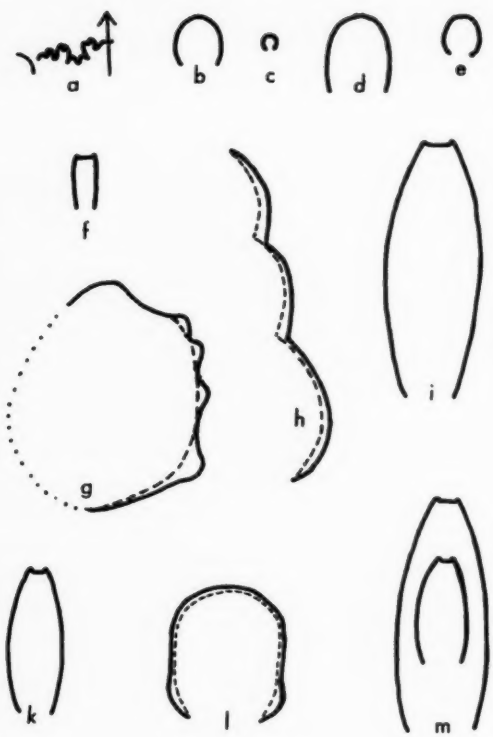
Ostlingoceras brandi Young, n. sp.

Pl. 40, figs. 4,5,7; Text-fig. 1h.

The holotype, UT 10281, is from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas.

The conch is turriliticonic, sinistral, very high spired, the number of whorls is unknown because of the erosion of apertural and apical ends. The whorl section is oval both costally and intercostally.

The ornamentation consists of low ribs, about 20 per whorl, some of which appear to bear incipient papillae. The costae and intercostae are about equal in width, and the ends of the ribs abut against the preceding and succeeding whorls, extending the full width of the whorl from spiral suture to spiral suture with even strength.



TEXT-FIG. 1

a-e—*Pesudouhligella elgini* Young, n. sp. *a*, suture of holotype at a 15 mm. diameter, *b*, whorl section of holotype at 15 mm., UT 10782A (*See also* Pl. 39, fig. 18); *c*, whorl section of Ut 10743A at a diameter of 5 mm. (*See also* Pl. 39, figs. 12–17); *d*, whorl section of UT 10782B at a diameter of 22.5 mm. (*See also* Pl. 39, figs. 19,20); and *e*, whorl section of UT 10741 at a diameter of 12 mm.; all ×1.

f,i,k,m—*Neopulchellia brundrettei* Young, n. sp. *f*, Whorl section at a diameter of 13 mm. of juvenile individual questionably referred to this species, UT 10739 (*See also* Pl. 39, figs. 1–3); *i*, whorl section of UT 10735 (*See also* Pl. 1, fig. 33); *k*, whorl section of UT 10744 at a diameter of 38 mm. (*See also* Pl. 39, fig. 38); and *m*, whorl sections of holotype, UT 10734, at diameters of 27 and 50 mm. (*See also* Pl. 39, figs. 35–37); all ×1.

g—*Hypoturrilites* n. sp. Whorl section of UT 10285, ×1. (*See also* Pl. 39, fig. 32).

h—*Ostlingoceras brandi* Young, n. sp. Whorl profiles of holotype, UT 10281, ×1. (*See also* Pl. 40, fig. 4).

l—*Watinoceras* n. sp. Whorl section of UT 10782E, ×1 (*See also* Pl. 40, fig. 10).

The aperture and sutures are not preserved.

Remarks.—*Ostlingoceras brandi*, n. sp., is placed in this genus instead of *Euturrilites* because its costation appears to be more easily derived from an *Ostlingoceras* lineage than from a *Turrilites* lineage. Without a more nearly complete ontogeny to study, the *Ostlingoceras* assignment cannot be completely justified. The flanks of *O. brandi*, n. sp., are not as flattened as in most species of the genus, but according to Arkell, Kummel & Wright (1957) flattening is not necessary in later species of the genus. The

EXPLANATION OF PLATE 39

FIG. *1–3*—*Neopulchellia brundrettei* Young, n. sp. (?). A juvenile individual that must belong to this species, but since it was separated from any adult, cannot be definitely identified; UT 10739, ×1 (*See also* Text-fig. 1f).

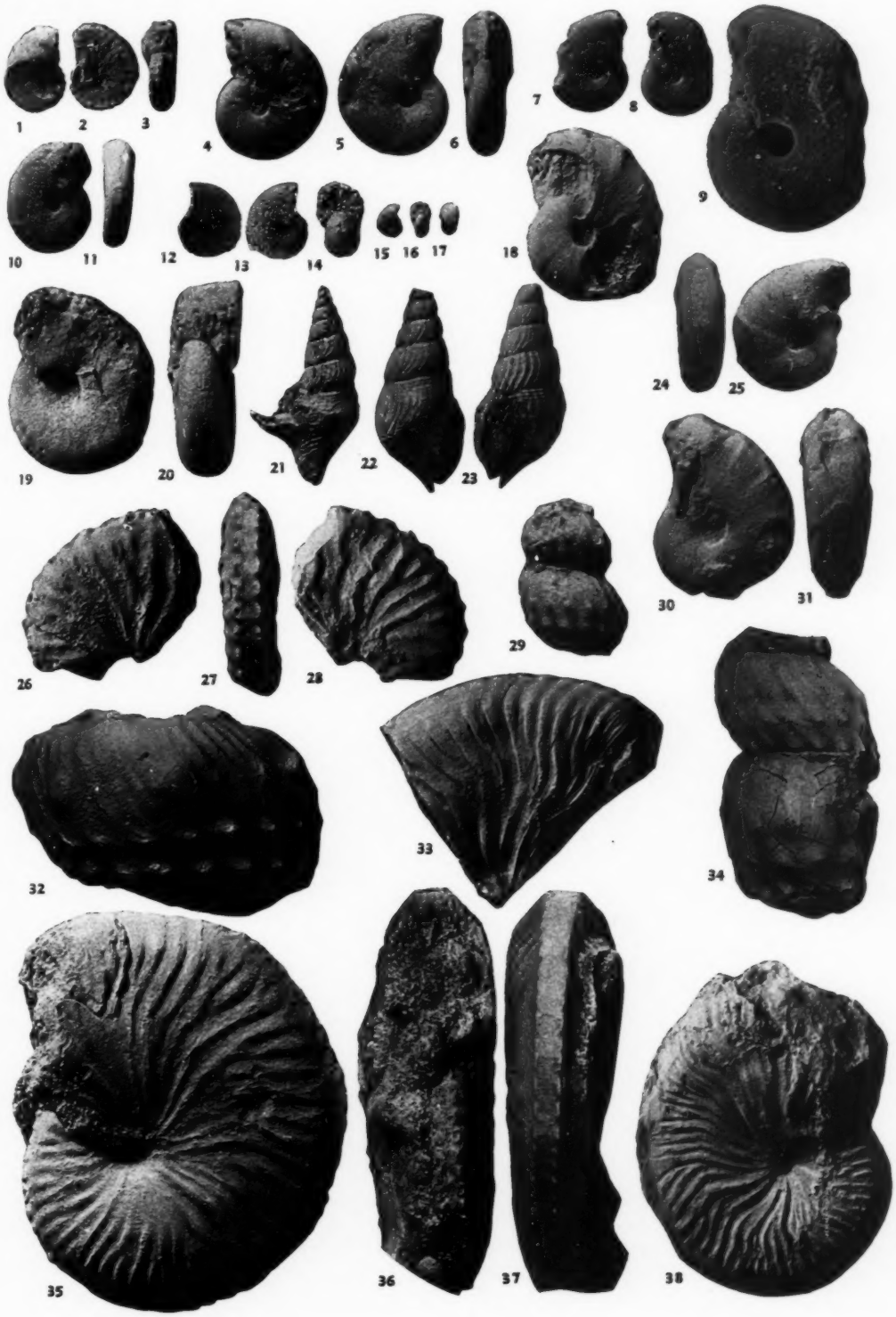
4–20,24,25,30,31—*Pseudouhligella elgini* Young, n. sp. *4–6*, Lateral and ventral views of UT 10782D; *7–9*, lateral views of UT 10740· *10*, lateral view of UT 10294; *11*, ventral view of UT 10796; *12–17*, various views of UT 10743A (*See also* Text-fig. 1c); *18*, lateral view of holotype, UT 10782A (*See also* Text-figs. 1a,b); *19*, *20*, lateral and ventral views of UT 10782B (*See also* Text-fig. 1d); *24,25*, ventral and lateral views of UT 10332; and *30*, *31* lateral and ventral views of UT 10782C. *4–8,10,11,15–18,24,25,30*, and *31* all ×1: *9,12–14* all ×2.2.

21–23—*Anchura* sp. *21*, UT 10791B and *22,23*, UT 10791A; Both ×1: The only other mollusk found in good preservation with the ammonites.

26–28,33,35–38—*Neopulchellia brundrettei* Young, n. sp. *26–28*, Lateral and ventral views of UT 10282; *33*, lateral view of UT 10735 (*See also* Text-fig. 1i); *35–37*, lateral and ventral views of holotype, UT 10734 (*See also* Text-fig. 1m); and *38*, lateral view of UT 10744 (*See also* Text-fig. 1k); all ×1.

29,34—*Ostlingoceras davisense* Young, n. sp. *29*, Lateral view of UT 10287 and *34*, lateral view of UT 10286, holotype: both ×1.

32—*Hypoturrilites* n. sp, Lateral view of whorl of UT 10285, ×1 (*See also* Text-fig. 1g).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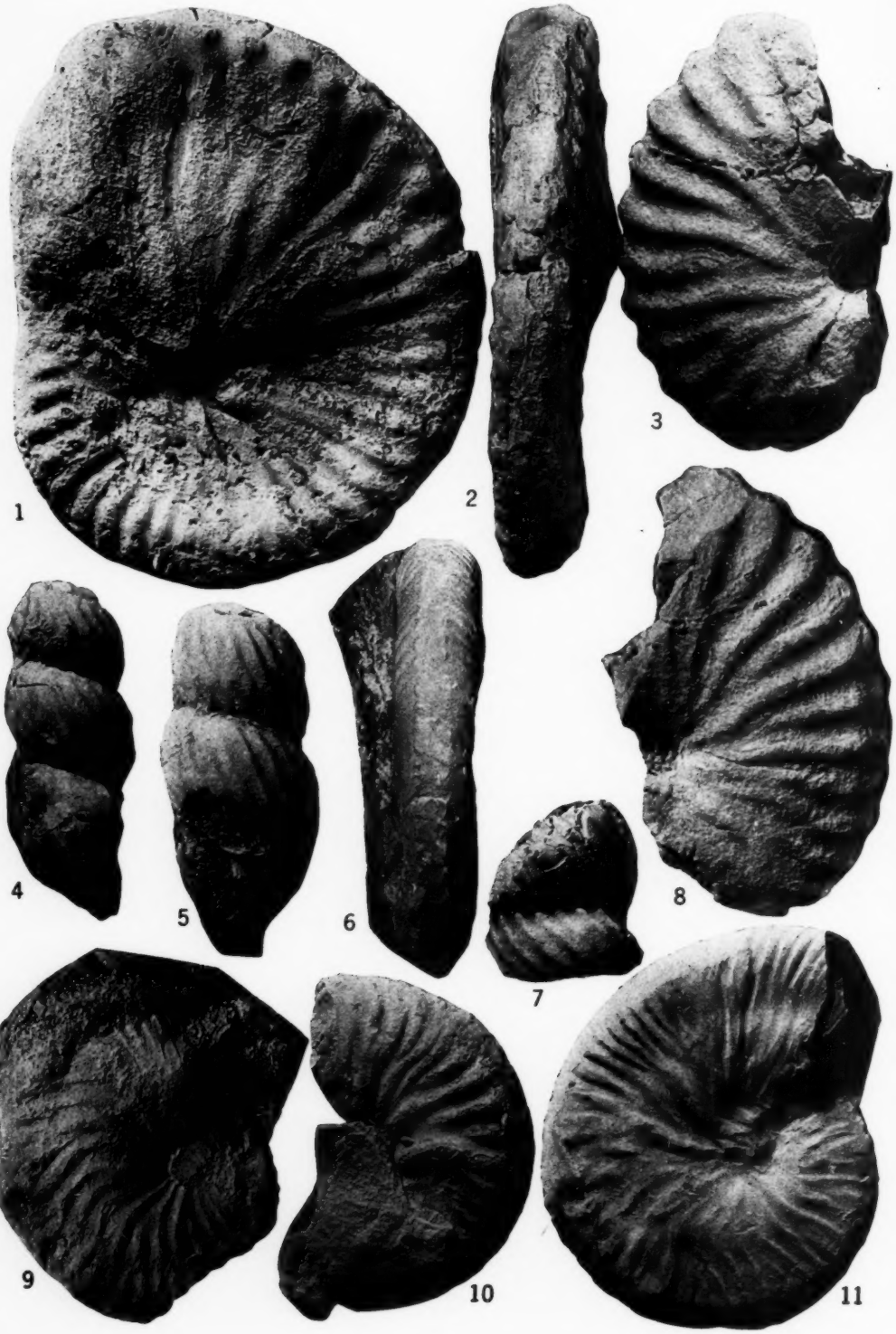
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oblique ribs and decreased nodosity differentiate *O. brandi* from other species of the genus.

Horizon and locality.—Base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas.

OSTLINGOCERAS DAVISENSE Young, n. sp.
Pl. 39, figs. 29,34

The holotype, UT 10286, came from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas.

The conch is turriliticonic, sinistral, very high spired, with the number of whorls unknown because of erosion of the apertural and apical ends. Whorl section oval in young, becoming flatter in the adult.

The ornamentation consists of from 14 to 16 ribs per volution, extending from spiral suture to spiral suture; ribs vary in strength, being weaker on the upper half of the whorl, but not becoming discontinuous. Costae and intercostae are about equal in width. The ends of the ribs abut against the preceding and succeeding whorls. Each rib bears three prominent nodes, the upper row of nodes positioned at mid-flank or just superior to mid-flank, the lower row abutting against the succeeding whorl, and the middle row intermediate between the upper and lower rows.

The aperture and sutures are not preserved.

Remarks.—As with *Ostlingoceras brandi*, n. sp., *O. davisense*, n. sp., is classified in *Ostlingoceras* because it is thought that the costation would be more easily derived from an *Ostlingoceras* lineage than from a *Turrilites* lineage. The flanks are not as flattened as in most *Ostlingoceras*. *O. davisense* is easily distinguished from *O. brandi* by its strong nodes contrasted with the weak papillae of the latter.

Horizon and locality.—Two individuals are from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas.

Suborder AMMONITINA Hyatt, 1889
Superfamily ACANTHOCERATACEAE Hyatt, 1900
Family ACANTHOCERATIDAE Hyatt, 1900
Subfamily MANTELLICERATINAE Hyatt, 1903
Genus NEOPULCHELLIA Collignon, 1929

NEOPULCHELLIA BRUNDRETTEI Young, n. sp.
Pl. 39, figs. 1–3,26–28,33,35–38; Pl. 40, figs. 6,9,11; Text-fig. 1f,i,k,m.

The holotype, UT 10734, is from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; probably Lower Cenomanian.

Oligogyral, concentrumbilicate, perangustumbilicate (U = 0.0 to 11.2), craterumbilicate; whorl section high and narrow with height/width ratio varying around 1.75 at small diameters (6 mm.), increasing to almost 3.00 at intermediate diameters (30 to 40 mm.), and decreasing to 2.25–2.50 at more advanced diameters. Overlap is to the umbilical shoulder. The costal whorl section parallels the intercostal section; the flanks are slightly arched laterad, and the venter is tabulate; because the venter is bounded on each side by a row of small clavae it appears to be concave; it is not, except in costal section.

The ornamentation consists of low, falcoid ribs, some of which almost approach bicon-

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EXPLANATION OF PLATE 40

FIG. *1,2*—*Utaturiceras* (?) sp. Lateral and ventral views of UT 10334, a badly crushed individual, and the only one of species in the collection.

3,8—*Metoicoceras* sp. Lateral views of UT 10257, an unsilicified fragment from a higher level than the other fossils in the collection.

4,5,7—*Ostlingoceras brandi* Young, n. sp. *4*, Lateral view of UT 10281, the holotype (*See also* Text-fig. 1h); and *5,7*, lateral views of UT 10284 and UT 10782E; all ×1.

6,9,11—*Neopulchellia brundrettei* Young, n. sp. *6,11*, Ventral and lateral views of UT 10737; and *9*, lateral view of UT 10279; both ×1.

10—*Watinoceras*, n. sp. Lateral view of UT 10782F, ×1 (*See also* Text-fig. 1l).

cavity. Rib alignment is generally rectiradiate, and exibits the unusual property of having the steep slope apicad and the gentle slope aperturad; at diameters exceeding 40 mm. there is a sharp decrease in rib strength about 3 mm. from the ventral clavae; there is also a sudden increase in the curvature of convexity at this locus, before the flank flattens completely at the clavae. At diameters of 60 mm. there are 50, more or less, ribs per volution, of which about 10 reach the umbilicus. The other 40 or so ribs intercalate without any pattern, a rib being added wherever there is sufficient space; an intercalating rib may extend almost to the umbilicus or be only a few mm. long just dorsad of the shoulder, depending on the space available.

The juvenile individual, UT 10739, which seems to belong to this species, has about 28 ventral (shoulder) clavae at a diameter of 13.5 mm.; at a diameter of 9 mm. the first faint ribs begin to appear on the second half of the flank only; later they spread to all of the flank.

The aperture is not preserved on any of the silicified shells, but UT 10735 is within only a few mm. of the aperture, and is a fragment of the apertural portion of the body chamber. In UT 10734 the last septum is at a diameter of 41 mm., and the body chamber occupied more than 180 degrees of the volution beyond that diameter. On other individuals it is not possible to differentiate the phragmacones from the body chambers. UT 10737 shows a ribbing at the apertural end which seems to be indicative of near aperture ribbing. The shell is 0.6 mm. thick on the venter of UT 10737 at a diameter of 60 mm. On UT 10282, at an estimated diameter of 35 mm., the shell is about 0.3 mm. thick.

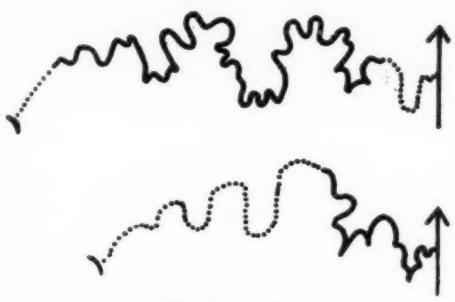
The ribs are just as sharp on the internal nodes as on the replacements. The ultimate size of the species is unknown, but UT 10737 shows a ribbing that is characteristic near the aperture of adults of many species of ammonites (Pl. 40, figs. 6,11).

It was possible to recover a suture on UT 10734 (Text-fig. 2), and it is remarkably like the suture of *Neopulchellia gignouxi* Collignon, with a small ventral lobe, a remarkably wide first lateral saddle in which the auxiliary lobe is extremely large and asymmetrically positioned ventrad. The first lateral lobe is long, the second lateral lobe only half as long as the first, and the third and fourth lobes are visible, but much reduced. The remainder of the suture was not recovered.

Measurements of several individuals are as follows, the letter symbols being those of Young (1957).

	D	U	H	W	H/W	P	S	B	T
UT 10739	13.5	00.0	59.0	29.5	2.00				
	10.0	00.0	50.0	27.0	1.85				
	6.0	00.0	62.0	35.0	1.76				
UT 10737	60.0	10.8	47.5	20.0	2.37	11	45	—	56
	50.0	11.0	54.0	21.0	2.57				
	40.0	11.2	59.0	22.5	2.50				
UT 10282			21.0	8.0	2.66				
UT 10735			35.0	12.0	2.92				
UT 10279	40.0	6.3	65.0	23.5	2.74				
UT 10744	40.0	2.5	57.5	27.5	2.08				
	20.0	—	63.5	26.5	2.38				
	25.0	—	66.0	26.0	2.54				
UT 10734 holotype	60.0	5.0	55.0	27.7	2.05	10	40	—	50
	50.0	4.6	60.0	24.0	2.50				
	40.0	4.2	63.5	22.5	2.84				
	30.0	3.3	66.7	23.1	2.86				

Observations.—The generic assignment of *Neopulchellia brundrettei*, n. sp., is definitely a problem. The species described by Collignon (1928–1929) are pyritic juveniles, and no adult individuals have heretofore been described. The juvenile individual, UT 10739, bears a striking resemblance to "*Submantelliceras*" *suzannae* (Pervinquiere), and especially to the individuals described by Collignon (1928, Pl. XVII, figs. 14,15,15a). This resemblance to "*S.*" *suzannae* is greater than is the resemblance to the species of *Neopulchellia* described by Collignon (1928–1929) except that *N. brundrettei*, n. sp., never develops the submantellicerine



TEXT-FIG. 2

Neopulchellia brundrettei Young, n. sp. Suture of holotype, UT10734, at a diameter of 41 mm., ×2. (*See also* Pl. 39, figs. 35–37 and Text-fig. 1m).

ventral clavae and ventrolateral nodes; only the ventral clavae. On the other hand, N. *Brundrettei* has a continuous swelling on the shell at the position of the ventrolateral nodes in the submantellicerines, but it probably has no phylogenetic interpretation.

I had originally considered this species a *Forbesiceras* of the group of *F. subobtectum*, but being unable to find a suture published on that species the comparison could not be completed. Furthermore, *N. brundrettei* possesses no midline ornamentation or ventral ornamentation of any kind at any growth stage; it has only the bounding rows of clavae, bounding the venter. Subsequent definition of a suture so similar to that of *N. gignouxi* Collignon discouraged any further attempt to assign *N. brundrettei* to *Forbesiceras*. On the other hand the *Neopulchellia* assignment is less than satisfactory. Although UT 10739 is more submantellicerine than is the juvenile of *N. gignouxi*, the comparison of juveniles is not a desirable procedure; the generic assignment on a suture alone is a hazardous procedure. Until all of the problems of the "submantellicerines" are solved many such generic assignments as this will remain in doubt.

Horizon and locality.—Base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; probably Lower Cenomanian.

Subfamily METOICOCERATINAE Hyatt, 1903
Genus UTATURICERAS Wright, 1956
UTATURICERAS? n. sp. (?)
Pl. 40, figs. 1,2

A fragmental and crushed individual, UT 10334, may belong to this genus, but it is so crushed as to be unidentifiable. The maximum diameter is 84 mm. The whorl section is higher than wide, but because of the crushed condition, no measurements can be trusted. There are about 37 ribs in the outer whorl, each rib bearing a single ventrolateral node, just faintly clavate. The last dozen or so ribs are flexuous; the others straight and prosiradiate in the adult. Since the juvenile is unknown and the individual is crushed the identification will never be exact.

Horizon and locality.—Base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; Upper Cenomanian.

Genus METOICOCERAS Hyatt, 1903
METOICOCERAS cf. *M. bösei* Jones, 1938
Pl. 40, figs. 3,8

The individual of *Metoicoceras* illustrated on Plate 40 is from a horizon somewhat above the rest of the fossils described in this paper; but still low in the Boquillas formation.

This fossil is higher than wide, the height/width ratio being about 1.9. There are about 16 slightly sinuous ribs per half-volution, usually a primary rib alternating with a secondary rib. All ribs bear low ventral clavae and indistinct shoulder nodes.

The Boquillas species is not as inflated as *M. swallovi* (Shumard) or *M. ornatum* Moreman; it is one of those few species of *Metoicoceras* which are flattened and which possess faintly sinuous ribs and very high whorls, as in *M. kanabense* Hyatt, *M. "whitei"* in Adkins (1928), *M. acceleratum* Hyatt, and *M. bösei* Jones (1938), particularly the form illustrated as *Metoicoceras* n. sp. by Böse (1920, Pl. 12, figs. 1,2). The Boquillas form is probably very close to Böse's, but the rib density is slightly greater. The rib density is the same as the forms illustrated by Jones (1938, Pl. 10, figs. 1,3), but the ribs in the Boquillas specimens are more sinuous than in Jones's. This fossil indicates a Lower Turonian (certainly not older than the top of the Cenomanian) age for the strata in which it occurs.

Horizon and locality.—Lower Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; Lower Turonian.

Subfamily MAMMITINAE Hyatt, 1900
Genus WATINOCERAS Warren, 1930
WATINOCERAS, n. sp.
Pl. 40, fig. 10; Text-fig. 11

A fragment, one-half volution, of an individual, UT 10782F, appears to belong to Warren's genus. As in the preceding description of *Utaturiceras?*, n. sp., the identification of this fragment leaves much to be desired. The whorl section is higher than wide, with flexuous rectiradiate ribs intercalated and primary; there are umbilical bullae on the primary ribs, and ventrolateral bullae, one row, at a diameter of about 40 mm. From the 40 mm. diameter aperturad, and perhaps at earlier diameters, the ribs pass over the venter, forming chevrons with the apices aperturad. The generic assignment of this individual must remain in doubt because of its poor preservation. The assignment rests largely on the ribs passing over the venter in chevrons.

Measurements of the fragment are as follows:

	D	U	H	W	H/W
UT 10782F	50.0	17.0	45.0	28.0	1.61

Horizon and locality.—Base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; Upper Cenomanian.

Superfamily DESMOCERATACEAE Zittel, 1895
Family DESMOCERATIDAE Zittel, 1895
Subfamily DESMOCERATINAE Zittel, 1995
Genus DESMOCERAS Zittel, 1894
Subgenus PSEUDOUHLIGELLA Matsumoto, 1942
DESMOCERAS (PSEUDOUHLIGELLA) ELGINI Young, n. sp.
Pl. 39, figs. 4–20,24,25,30,31; Text-figs. 1a–e

The holotye, UT 10782A, is from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Trans-Pecos Texas; probably Lower Cenomanian.

Oligogyral, generally concentrumbilicate, steeply subgradumbilicate, angustumbilicate; whorl section oval, higher than wide at diameters beyond 6 mm., the height/width ratio ranging from 1.4 to 1.6 at diameters of more than 20 mm.; from 1.0 to 1.4 at diameters of 10 to 20 mm.; from 1.0 to 1.3 at diameters of 5 to 10 mm.; and from 0.56 to 1.1 at diameters of 2 to 5 mm.; height /width ratio generally increasing with shell diameter. Overlap is not quite to the umbilical shoulder. The ornamentation consists of growth lines, sometimes visible on the silicified casts; low striae or very small folds at mid flank on some juveniles; and a variable number of constrictions which are restricted to the body chamber or the body chamber and the preceding one-half volution. The constrictions are weakly biconcave on the outer one or two whorls; no constrictions were observed on any individuals at diameters of less than 9.5 mm., the first constriction appearing at 9.5 mm. on UT 10794, at 10.4 mm. on UT 10741, and at 11.5 on UT 10740. No lateral striae were observed on any individuals at the same diameters as constrictions; striae, when present, always occur on the whorls preceding the constrictions. The number of constrictions is variable because they seem only to occur on the last whorl, that is, the body chamber and the preceding half volution. Thus UT 10782D has 5 constrictions only, and all are on the body chamber; UT 10782A has 7 constrictions, two preceding the last septum and 5 on the body chamber; UT 10740 has three constrictions, all on the body chamber, but the body chamber is incomplete. UT 10382 has 9 constrictions, 2 preceding the body chamber, 7 on the body chamber. UT 10795 has 5 constrictions on the last two-thirds of the last whorl, their relation to the body chamber being undetermined. UT 10742 at a diameter of 9 mm. has no constrictions, but has 2 or 3 low striae at mid flank at a diameter of about 7 mm., and UT 10782D has low striae at a diameter of about 9 mm., preceding the 5 constrictions on the body chamber, the body chamber beginning at about a diameter of 13 mm.

Any actual aperture, if preserved, is crushed, but the growth lines follow the constrictions, being biconcave in the more adult individuals, and, in the largest individuals, forming a moderately pronounced ventral platform.

The shell is thin, being about 0.55 mm. thick on the venter of a larger individual, UT 10782C.

The ultimate size of the species may be estimated because a large number of individuals retain parts of the body chamber. The diameters of the shells at the last septum of several individuals are: 15 mm. 12.5

mm., 13.0 mm., 16.0 mm., 14.5 mm., and 13.0 mm. UT 10782C seems to bear a fragment of the apertural margin, and in this individual the body chamber occupies about 220°. The number of individuals, the maximum diameters of which are 27 mm., 28 mm. (with fragments of apertural margin intact), 25.5 mm., 22.0 mm., 21.0 mm., etc., indicates that the species is not large; all of these individuals retain parts of the body chamber.

The suture is not as well preserved as desirable, and could not be completed to the umbilical seam. The first lateral saddle is narrower than the ventral lobe and narrower than the first lateral lobe, and is bipartite. The first lateral lobe is tripartite. This is almost identical with the description of the suture of *Desmoceras* sp. by Stephenson (1953).

The measurements of several individuals follow:

	D	U	H	W	H/W	No. of Constrictions
UT 10782C	30.0	13.6	50.0	33.5	1.50	9
	25.0	16.0	48.0	38.0	1.32	
	15.0	20.0	53.5	46.5	1.14	
Ut 10782D	21.5	10.2	51.0	35.0	1.47	5
	15.0	10.0	56.5	36.5	1.54	
	10.0	10.0	50.0	40.0	1.25	
UT 10782B	22.5	13.3	57.5	40.0	1.44	
UT 10782A holotype	27.0	13.0	54.0	36.0	1.52	6
	21.0	14.2	52.5	35.5	1.46	
	17.0	11.8	50.0	38.0	1.31	
UT 10740	16.0	13.7	53.0	37.5	1.41	3
	10.0	10.0	57.0	45.0	1.27	
	7.5	10.7	62.0	53.5	1.11	
UT 10382	22.0	13.6	48.0	34.0	1.40	9
	15.0	13.3	50.0	36.5	1.36	
	10.0	—	53.0	48.0	1.10	
UT 10796	17.0	14.7	47.0	32.0	1.45	9
	13.0	15.3	50.0	33.0	1.51	
UT 10741	18.0	13.9	51.0	39.0	1.31	5
	15.0	13.3	53.5	40.0	1.33	
	10.0	13.0	55.0	45.0	1.22	
UT 10794	17.0	11.7	53.0	41.0	1.28	5
	10.0	10.0	53.0	50.0	1.06	
UT 10795	11.5	8.7	52.0	46.0	1.13	
	7.5	—	60.0	53.5	1.12	
	5.2	—	58.0	63.5	0.91	
UT 10742	9.0	8.9	58.0	44.5	1.30	
	5.0	14.0	64.0	58.0	1.10	
UT 10743C	6.3	8.0	51.0	57.5	0.89	
	4.5	—	60.0	62.5	0.96	
	3.2	—	59.5	72.0	0.83	
UT 10743B	7.2	9.7	58.5	51.5	1.13	
	5.3	—	56.5	60.5	0.94	
	3.4	—	67.5	82.5	0.82	
UT 10743A	5.0	10.0	60.0	64.0	0.94	
	4.0	—	57.5	67.5	0.85	
	2.3	—	56.5	87.0	0.65	

Remarks.—Only a few forms related to *Pseudouhligella elgini*, n. sp., have been described. *P. japonica* Yabe and other Japanese forms (Matsumoto, 1954) are much larger species, and the adult constrictions of *P. elgini* are not as strongly biconcave as they are in the Japanese species. The small individuals described by Stephenson (1953) as *Desmoceras* sp. agree very closely with the juveniles of *P. elgini*, both in whorl conformation and in the elements of the suture. Stephenson reports part of the body chamber on the individual in his figures 1 and 2 on his plate 45, but the picture appears to show indications of suture clear to the end. One of Stephenson's specimens occurs with *Metoicoceras swallovi* (Lower Turonian ?), whereas *P. elgini* occurs with *Neopulchellia brundrettei*, n. sp. (Lower Cenomanian). Small desmocerids occurs at many localities in Texas (*e.g.*, Aquilla Creek and the Rio Grande embayment have

yielded many individuals from the Eagle Ford formation), but these all seem to be from a higher horizon than *P. elgini*; they are from horizons more closely equivalent to that of the forms illustrated by Stephenson; all of these specimens are poorly preserved.

Horizon and localities.—Pseudouhligella elgini, n. sp., is known from the base of the Boquillas formation, northeastern flank of the Davis Mountains, Jeff Davis County, Texas; probably Lower Cenomanian, and from the slump block north of the cattle guard on the Nevill Ranch road, about 15 miles west of Toyah, Reeves County, Texas.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 295–303, PLS. 41–43, 10 TEXT-FIGS., MARCH 1958

SOME PREVIOUSLY UNKNOWN MORPHOLOGICAL STRUCTURES OF *CARCINOSOMA NEWLINI* (CLAYPOLE)

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ABSTRACT—An unusually well-preserved whole specimen of *Carcinosoma newlini* (Claypole) from the Silurian Kokomo dolomite at Kokomo, Indiana, exhibiting the original coloration and underside, as well as a definitely segmented structure posterior to the terminal spike, is described. A complete restoration of dorsal and ventral sides is given.

THE well-known eurypterid fauna of the Silurian Kokomo dolomite at Kokomo, Indiana, is remarkable not only because of the unusually complete and well preserved specimens but because the species found in this bed are considerably different from those found elsewhere in North America. In many respects the eurypterid bed shows affinities to the Ludlow (?) of the Lesmahago district, Scotland. The Lesmahago eurypterids are, however, considered not to be more recent than Wenlock by Lemont (1955) but are thought to be Ludlow in age by Denison (1956). On the basis of the eurypterids the Lesmahago forms are more closely similar to those of the Middle Ludlow, Mocktree shales of Leintwardine, England, than any other assemblage.

The discovery of the Kokomo eurypterids was first announced by Claypole (1890a) who, from specimens collected by C. E. Newlin, erected the new genus *Eurysoma*, with *E. newlini* as type species. He referred the remainder of the specimens to *Eurypterus lacustris* Harlan, a determination that was admittedly hasty (Claypole, 1890a). In the same year, Claypole (1890b) noted that *Eurysoma* was preoccupied and substituted the name *Carcinosoma* for his genus. Later in 1894, he described another new species as *Carcinosoma ingens*, considering that the outlines of the appendages and greater size separated it from his previously established *C. newlini*. Miller & Gurley (1896) described *Eurypterus kokomoensis* from the same bed and locality. This form undoubtedly represents the species which Claypole had tentatively identified as *Eurypterus lacustris*. Clark & Ruedemann (1912) erected in their classic monograph a new subgenus of *Eurypterus* under the name *Onychopterus* for *Eurypterus kokomoensis* Miller & Gurley and described two additional species as *Eurypterus ranilarva* and *Drepanopterus longicaudatus*. They further noted that the genus *Carcinosoma* was a synonym of *Eusarcus*. Størmer (1934), however, revealed that the generic name *Eusarcus* was preoccupied, and he reinstated Claypole's name *Carcinosoma*. Kjellesvig-Waering (1948) described two new forms from the same fauna, namely *Pterygotus* (*Pterygotus*) *ventricosus* and *Onychopterus limuloides*, but he considered *Eurypterus ranilarva* Clarke & Ruedemann to be a synonym of *Onychopterus kokomoensis* (Miller & Gurley), besides raising *Onychopterus* from subgeneric to generic rank. Størmer, 1951, noted that the generic name *Onychopterus* was preoccupied and substituted the valid name *Onychopterella*. As thus defined, the eurypterid fauna of the Kokomo dolomite at Kokomo, Indiana, comprises the following species:

Carcinosoma newlini (Claypole)
Drepanopterus longicaudatus Clarke & Ruedemann
Onychopterella kokomoensis (Miller & Gurley)
Onychopterella limuloides Kjellesvig-Waering
Pterygotus (*Pterygotus*) *ventricosus* Kjellesvig-Waering

All of these species are distinct and are restricted to the Kokomo fauna.

The eurypterids of this fauna are preserved rather differently than those of most other areas. They are preserved in a fine-grained dolomite, and when freshly exposed, the integument, comprising chitin, retains many details, including the coloration. Obviously, the original chitin is preserved in an unaltered state, a condition likely due to the non-porous and impermeable character-

istics of the fine-grained dolomite, where replacement of the chitin did not occur or progress significantly. Together with the original coloration of the eurypterids, certain details are preserved in these specimens which are not present in most other eurypterid faunas. These include a specimen showing the alimentary canal (Ruedemann 1919), specimens with the outlines of the gill structures (Clarke & Ruedemann, 1912), and commonly the outlines of the doublures of each tergite and sternite. As stated above, nearly all the specimens recorded (except one which was broken off during collection) are preserved whole. The specimen retaining the alimentary canal, and the one described below which also retains a portion of this structure, indicate death *in situ* and not exuviae as with most other eurypterids. The completeness of the Kokomo specimens, as well as specimens retaining the alimentary canal, may indicate a catastrophic death for the eurypterids at the Kokomo locality.

The main purpose of this discussion is the description of another unusually well-preserved specimen of *Carcinosoma newlini* which is preserved nearly whole, but reveals for the first time the underside of the animal as well as the preservation of a distinct segmented shaft beyond the telson; the segmentation is a structure previously unknown in any of the Eurypterida. This specimen is an adult, approximately 40 cm. long; it is a male and reveals the coloration and certain details described below, hitherto unknown. The specimen was kindly loaned by Dr. Norman D. Newell of the American Museum of Natural History, to whom the writer wishes to express his gratitude.

Class MEROSTOMATA Dana, 1852
Subclass EURYPTERIDA Burmeister, 1843
Superfamily EURYPTERACEA Burmeister, 1845
Family CARCINOSOMATIDAE Strømer, 1934
Genus CARCINOSOMA Claypole, 1890
CARCINOSOMA NEWLINI (Claypole)
Pls. 41–43; text-figs. 1–10

Eurysoma newlini CLAYPOLE, 1890, Am. Geologist, v. 6, p. 260, fig. 1.

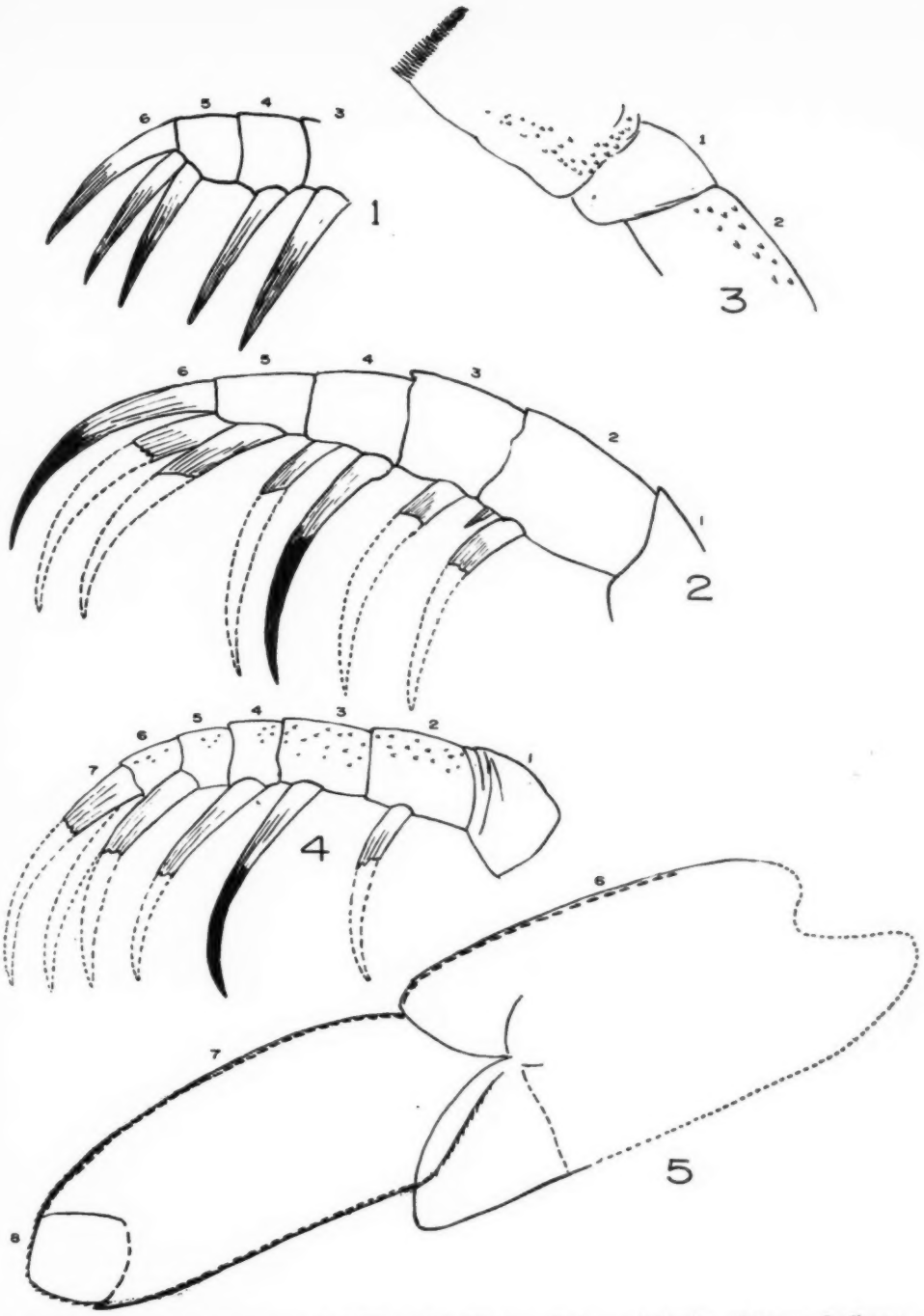
Carcinosoma newlini CLAYPOLE, 1890, ibid., v. 6, p. 400; CLAYPOLE, 1894, ibid., v. 13, p. 78; SARLE, 1903, N. Y. State Mus., Bull. 69, p. 1108; STØRMER, 1934, Skr. Vid-Akad. Oslo, 1. M.—N.Kl., no. 10, p. 104; KJELLESVIG-WAERING, 1948, Jour. Paleont., v. 22, p. 466; PRANTL & PŘIBYL, 1948, "Rozpravy," Státního Geologického ústavu Ceskoslovenské Republiky, Svazek 10, p. 97; STØRMER, 1955, Treatise on Invertebrate Paleontology, R. C. Moore, editor, Part P, Arthropoda 2, p. 34; RAW, 1957, Jour. Paleont., v. 31, p. 164.

Carcinosoma ingens CLAYPOLE, 1894, Am. Geologist, v. 13, p. 77–79, pl. IV.

Eusarcus newlini CLARKE, 1909, N. Y. State Mus., Bull. 133, p. 37; CLARKE & RUEDEMANN, 1912, N. Y. State Mus., Mem. 14, v. 1, p. 245–253, pl. 36, fig. 11, pls. 37–39, text-figs. 59–60; KINDLE, 1913, Amer. Jour. Sci., ser. 4, v. 36, p. 285; WOODWARD, 1913, Geol. Mag., v. X, p. 297; WILLIAMS, 1915, Canada Dep. Mines, Geol. Surv., Mus., Bull. 20, p. 3–4; O'CONNELL, 1916, Buffalo Soc. Nat. Sci. Bull., v. XI, p. 43; RUEDEMANN, 1919, Paleont. Contrib. New York State Mus.: N. Y. State Mus., Bull., 227–228, p. 92–95, figs. 33,34; DIENER, 1924, Fossilium Catalogus, I, Animalia, Part 25, Eurypterida, p. 21, Berlin.

The prosoma is trapezoidal in general outline; the anterior margin is roughly parallel to the base, whereas the lateral margins converge anteriorly to be truncated by the anterior margin. Antelateral margins and genal angles are gently curved. A very narrow rounded rim surrounds the prosoma. The entire prosoma is covered by elongated raised scale-like ornamentation. The lateral eyes are elliptical and are located on the antelateral angles. The ocelli are unknown, but they likely are small and located in the center of the dorsal shield.

All prosomal appendages are known except for the chelicerae. Walking legs (appendages II to V) are very stout strong structures which increase in size anteriorly, from No. V to No. III (figs. 1–4). The first walking leg (No. II) is considerably shorter than the following. Each walking leg is armed with numerous long curved striated spines, and each joint, for the most part, is armed with two spines. All walking legs are turned so that the venter faces forward, directing the great spines forward. The legs are flat and turned thus forward to form a formidable trap for the capture of prey (Pl. 42,43). It should be noted that this species is quite unlike *Carcinosoma scorpionis* (Grote & Pitt) in this respect, as the latter did not depend on the walking legs as a weapon but probably depended on the curved and possibly poisonous stinger. Therefore, the walking legs of *C. scorpionis* were weakly devel-



TEXT-FIGS. *1–5—Carcinosoma newlini* (Claypole), Silurian, Kokomo dolomite, Kokomo, Indiana:
1—Second appendage, or first walking leg, with joints 1–6. ×1.5.
2—Third appendage, or second walking leg, with joints 1–6. ×1.5.
3—Coxa and joints 1–2 of second walking leg. ×1.5.
4—Fifth appendage, or fourth walking leg with joints 1–7. ×1.5.
5—Distal end of swimming leg from ventral side, joints 6–8. ×1.5.

oped as contrasted with the strong structures of *C. newlini*.

Each joint of the walking legs is ornamented with elongated scales only on the posterior (dorsal) side. Each scale has its apex directed to the distal end of the legs. The coxae are not well known but that of the III appendage, the longest leg, was preserved and reveals that the gnathobase comprises numerous closely packed long slender teeth (Text-fig. 3).

The swimming leg is an overall long and strong structure with the paddle, joints 6 to 8 in particular, greatly elongated. The terminal joint is considerably enlarged, a characteristic of the genus. Along the inner joints, the ornamentation comprises distally directed elongated scales, whereas the paddle is bordered with a single row of flat elongated "scales" which, on the distal end and in the region of the last joint, grade into small slender spines (Text-fig. 5).

The metastoma is poorly preserved and remains almost unknown in this species. It probably is a broad shield as in the closely related *Carcinosoma scorpioides* (Woodward).

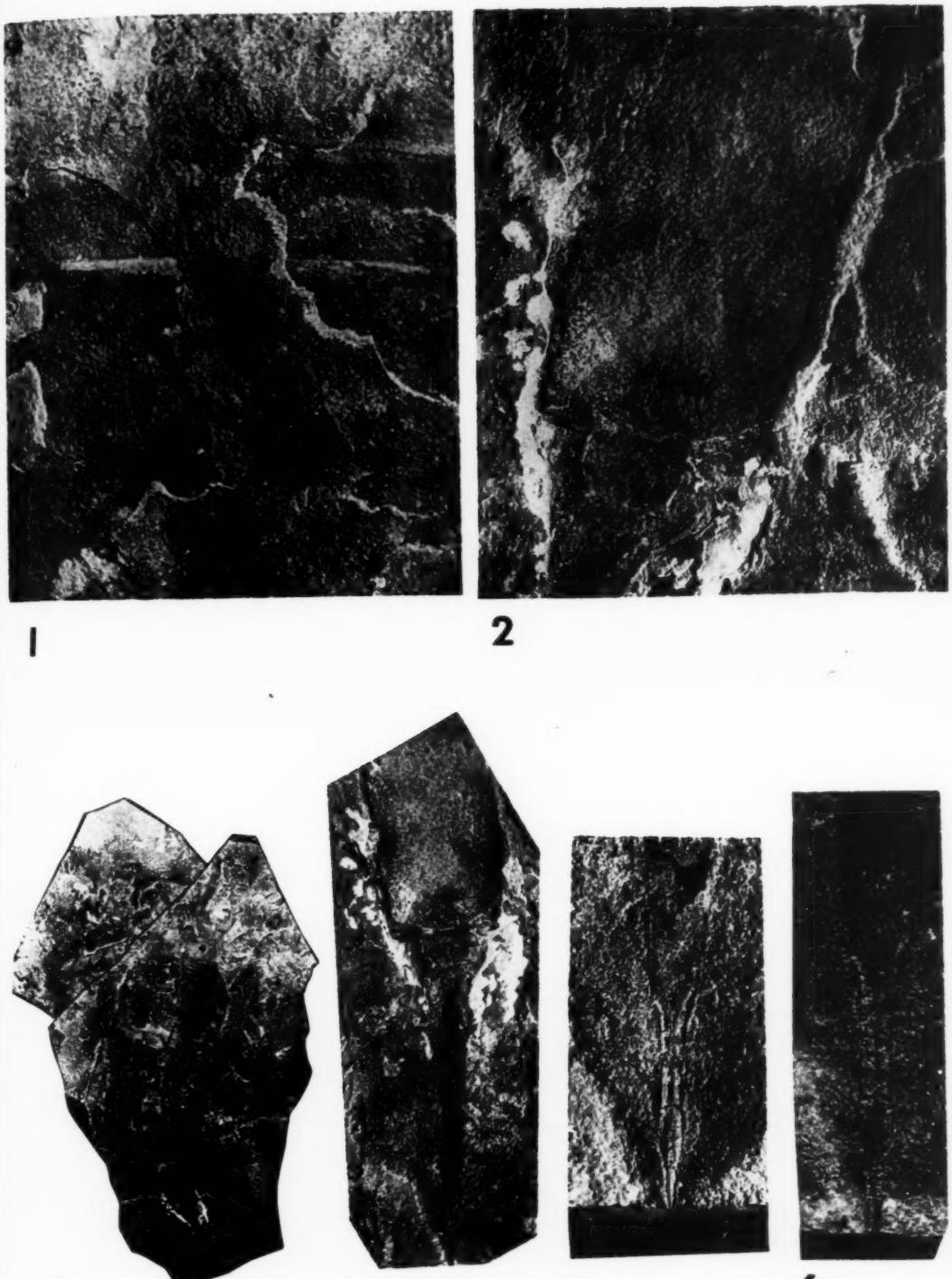
The dorsum of the metasoma comprises six tergites, all of which, except the first, are of approximately the same size. The first tergite is considerably narrower than the succeeding. Along with the first tergite of the metasoma, the mesosoma is nearly circular in outline (Text-fig. 7). Abrupt contraction occurs past the first tergite of the metasoma. The dorsal side is covered with small elongated scales.

The underside of the mesosoma comprises the operculum and four succeeding abdominal plates or sternites. The operculum consists of two wide plates sutured on the anterior part of the midsection. The median appendage, roughly club-shaped (Text-figs. 6,7) is a flat long single-jointed structure with a bulbous emarginate end. Along the middle part is a slightly raised apparently divided internal area. The anterior part of the median appendage is hastate. Internal tubules occur at the base of the hastate area. No openings to these internal tubules were noted, although two distinct depressions are present at the base of the hastate area of the median appendage (Pl. 41, fig. 1), that may represent external openings. It is noteworthy that the opercular flaps are not divided into three distinct plates as shown in the corresponding structure for *Dolichopterus jewetti* by Caster & Kjellesvig-Waering (1956) or by Raw (1957) in the case of *Eurypterus*. Furthermore, the operculum of *Carcinosoma* does not have deltoid plates or lateral lobes developed (Text-fig. 6). In this manner, the operculum rsembles more the type found in *Megalograptus* where no traces of either segmentation, deltoid plates, or lateral lobes are found in well preserved specimens. The median appendage of the specimen herein described is presumably of "Type A" (Størmer, 1933) which is considered a male. The female is mainly unknown, but Clarke & Ruedemann (1912) figure a specimen in which the median appendage is reflected through the dorsal surface and which is distinctly shorter than the form described herein. That specimen likely represents a female.

The median appendage is devoid of ornamentation, but the opercular flaps are covered with small semi-lunar to elongated scales considerably smaller than those present on the dorsal surface.

EXPLANATION OF PLATE 41

FIGS. *1–6—Carcinosoma newlini* (Claypole), Silurian, Kokomo dolomite, Kokomo, Indiana, Amer. Mus. Nat. Hist. acc. #502: *1*, Median appendage, turned to the right and upper part of appendage of succeeding sternite, the inner side of the dorsal tergites, with doublures, is present on each side of the median appendage, ×2; *2*, pretelson, or twelfth tergite, and upper part of telson, the two expanded structures, appearing bag-like on each side, may have been inflated in life, ×1.4; *3*, entire specimen ×1/7*th*; *4*, pretelson, terminal spike, and "post-telson" structure, ×0.6; *5*, enlargement of the "post telsonic" structure and posterior end of terminal spike, suture between No. 2 and No. 3 segments can be clearly seen, ×2; and *6*, enlargement of same section with light directed from a different source to reveal the segmentation beyond the expanded part of the "post-telson," ×2.5.



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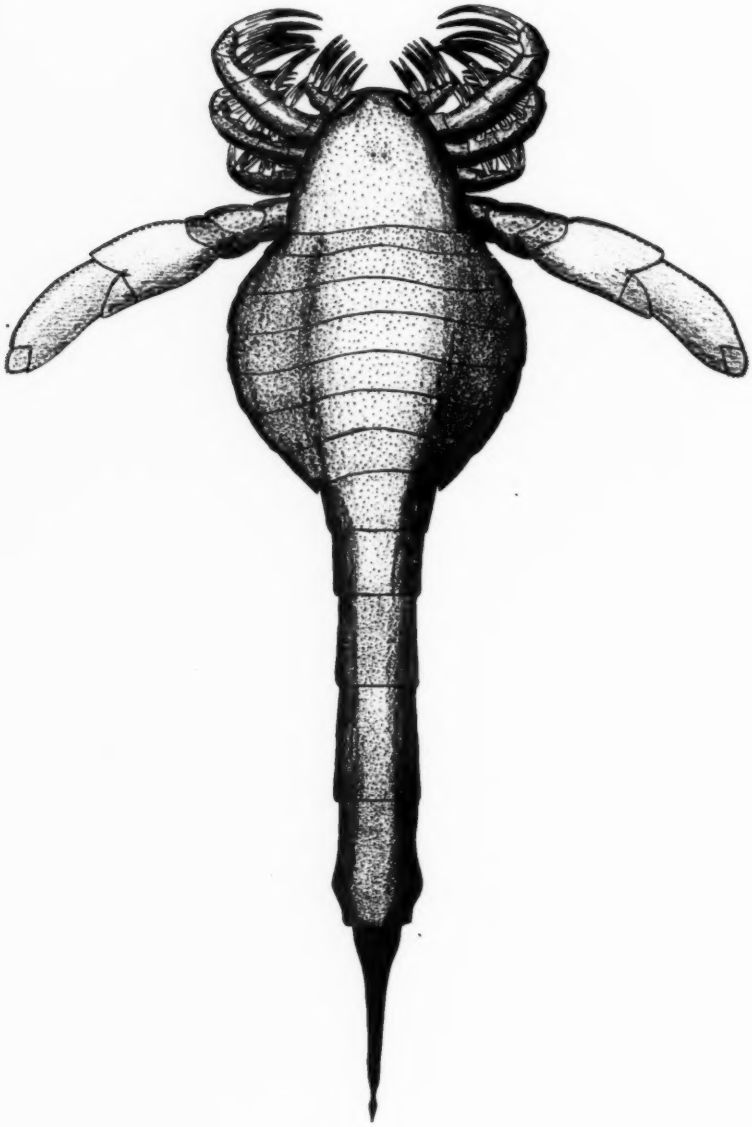

The succeeding four sternites, or abdominal plates, reveal interesting structures which likely represent vestiges of the endopodites. Each sternite, except the last, is divided along mid-section by a depressed suture; they are strong structures, each of which is bounded along the posterior edge by a doublure 3 mm. in length (Text-fig. 6). The second abdominal plate, or first plate posterior to the operculum, retains a paired bluntly lanceolate organ which disappears anteriorly. It occupies a position immediately below the mesial appendage of the operculum but is entirely independent of that structure (Text-figs. 6,7). *Hughmilleria socialis* Sarle exhibits the same independent relationship of the median appendage and the appendage of the first sternite (Clarke & Ruedemann 1912, Pl. 62, figs. 9,10 and Pl. 63, fig. 3) in both sexes. The second sternite also consists of two plates bounded by a depressed suture at midsection, with a much smaller lanceolate paired organ at the anterior part. The third plate retains only the deep suture but no median appendage, whereas the fourth or last sternite has a suture developed only on the anterior midsection and no trace of the suture on the rest of the plate. The gradation from the large mesial appendage of the operculum to progressively smaller median structures into sutures and in turn the almost complete disappearance of the median suture, is unusually well revealed in this eurypterid.

The seventh tergite of the opisthosoma has well developed posteriorly directed epimeral horns which form a deep emarginate area for the articulation of the rest of the metasoma. This depressed area is greater ventrally than dorsally and resulted in giving the tail, or metasomal tergites, great flexibility in a downward direction. Thus the tail could likely be bent ventrally into a rather tight arc.

The following tergites of the metasoma are greatly constricted; each is progressively longer and flattened in cross-section, a departure from the tubular or cylindrical tail of Carcinosomatidae such as *C. scorpionis* (Grote & Pitt) whose tail assemblage terminated in a curved possibly poisonous stinger and capable of being thrown vertically and anteriorly over the cephalothorax as in the scorpions. The metasoma of *Carcinosoma newlini* being flat, likely was used as a partial aid in swimming, as suggested by the expanded pretelson.

The last tergite, or pretelson, reveals a structure hitherto unknown in the Carcinosomatidae. This comprises two expanded areas on each side of the posterior half of the tergite. The expansion is slight but definite (Pl. 41, figs. 2,4, and text-fig. 8); the tergite measures in width 27.6 mm. immediately anterior to the expanded areas, 31.6 mm. at the expansion, and 27.2 mm. posterior to the expanded structures. It is possible that the two structures are inflated, but this can not be ascertained, as little or no relief is discernible in the specimen. More likely, the structures are either vestiges or an attempt at widening of the pretelson as an aid in swimming. *Megalograptus* has a well developed expanded pretelson, and it is suggested that a similar but far less developed structure is present in *Carcinosoma*. It again emphasizes the flattened nature of the mesosoma of *Carcinosoma* as against the cylindrical type of forms such as *C. scorpionis* (Grote & Pitt).

The entire metasoma is covered with scattered fine elongated scales.

The telson is stiletto-like, flattened, expanded anteriorly, and normally terminates in a spike. Beyond the spike, however, is a surprising structure hitherto unreported definitely in the Eurypterida. This comprises a definite prolongation of the telson into a distinct segmented elongated area. This segmented shaft has not been preserved in other Carcinosomatidae as it is generally broken or aborted during ecdysis. The segmented area (Pl. 41, figs. 4–6, Text-figs. 8,9) begins immediately posterior to the normal telson; attachment here can be ascertained by the presence of a distinct suture. From

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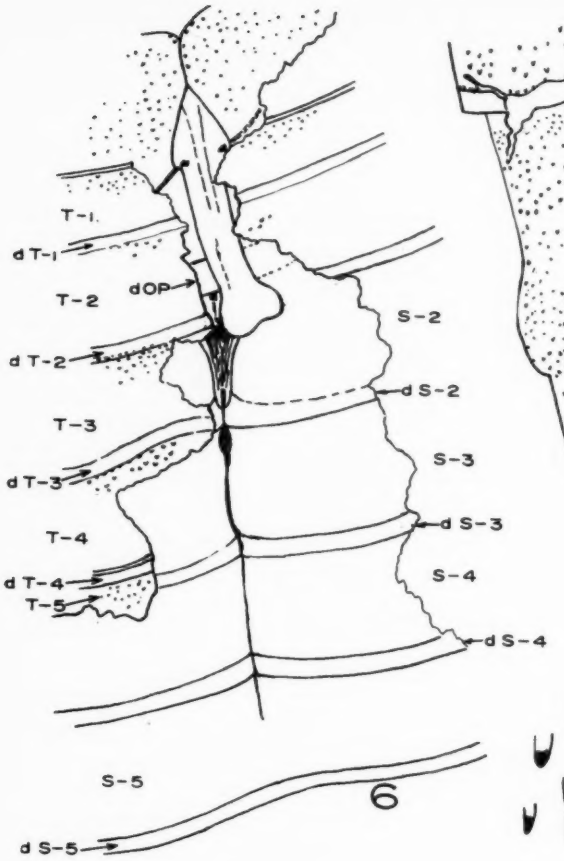
EXPLANATION OF PLATE 42

Dorsal aspect of *Carcinosoma newlini* (Claypole), Silurian, Indiana, ×1/6.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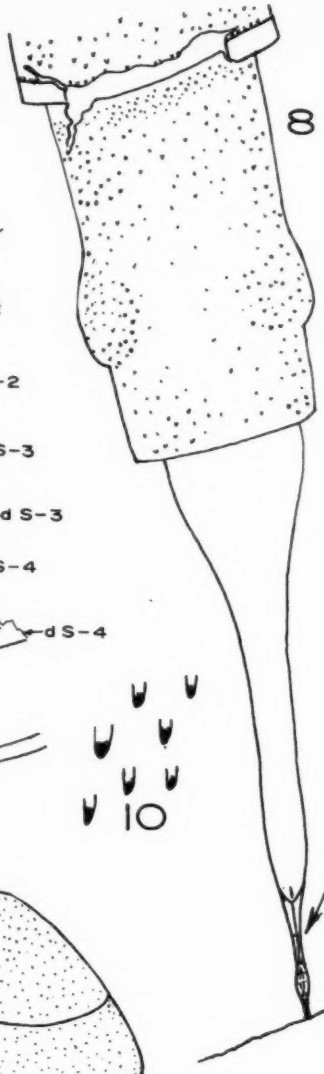
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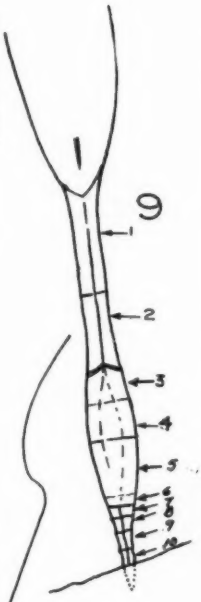
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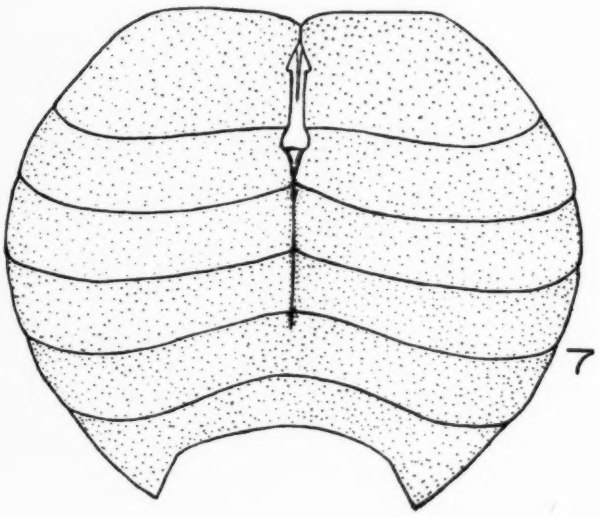
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the normal telson, the "post-telson" narrows greatly, it is carinated, and at mid-section reveals a definite suture. The area above this suture has been interpreted as the first segment of the post-telson. Segment No. 2 occupies the posterior half of the narrow shaft. From this narrow shaft, the post-telson expands to nearly double its width; a slightly flat wide carina occupies the central portion. Four segments have been established for this area. Beyond the expanded third to sixth segments are four distinct segments, carinated ventrally (Pl. 41, figs. 5,6). The sutures between the segments are limbate. The post-telson is unfortunately broken at the distal end, and it is not known if more than ten segments complete the distal end or if further structures as in *Salteropterus* occur beyond these segments. The segments measure in length as follows:

No. 1.—4 mm.
No. 2.—3.2 mm.
No. 3.—1.0 mm.
No. 4.—1.5 mm.
No. 6.—2.0 mm.
Nos. 7–10.—each slightly less than 1 mm.

In general, six of these segments are very distinct, whereas the other four, mainly in the expanded area, are but faintly preserved.

The writer (1951) noted that the telson of *Salteropterus abbreviatus* (Salter) from the Downtonian of the Welsh Borderlands retained an area beyond the normal telson which comprised a long tubular section that terminated in an expanded elongated definitely tri-lobed structure. For want of a better name, the writer used the term "post-telson" for this structure and further noted that longitudinal "cracks" might be sutures or segments, but this was not clearly established. In view of definite segmentation in *C. newlini* there seems little doubt that the post-telson of *Salteropterus* is also segmented. Raw (1957) has stated that the so-called telson of the eurypterids is not a true telson but a normal segment. The presence of definite segments, at least ten, beyond the normal "telson" of the Eurypterida, now known in two different genera (*Carcinosoma* and *Salteropterus*), should prove Raw's idea concerning the nature of the eurypterid "telson." There is no doubt that we are dealing with an important rudimentary structure of the eurypterids, the fuller understanding of which will greatly enhance our knowledge of the origin of these forms. It is important that the attention of paleontologists be directed toward the presence of these interesting vestigial segmented areas as undoubtedly more eurypterids will be discovered which retain this delicate and inconspicuous structure.

A part of the alimentary canal is faintly preserved in this specimen. Preservation of this organ is not sufficiently good to permit further description. It is reported mainly because it serves to show that the individual is not a cast off moult but died, apparently *in situ*.

The integument reveals the original coloration which, overall, is scorpionid in aspect. Little of the thin integument is preserved as much has been stripped away. Enough is present, however, to enable one to describe the general coloration. Throughout the dorsal side of the cephalothorax, mesosoma, and metasomal tergites the integument is light brown in color. The elongated scales (Text-fig. 10) are darker brown and grade into black at the apex of the scales. The smaller scales, or pustules, along the anterior edge of the metasomatic tergites are brown in color but contrast with the lighter brown of the integument. The operculum and abdominal plates are lighter brown, nearly buff in color, than the tergites

TEXT-FIGS. *6–10*—*Carcinosoma newlini* (Claypole), Silurian, Kokomo dolomite, Kokomo, Indiana:

6—Underside of mesosoma, including male median appendage of the operculum; the succeeding sternites with median appendages and sutures, posterior doublures, and ventral side of dorsal tergites.T-1 to T-5: tergites; d T-1 to d T-4: posterior doublures of tergites; S-2 to S-5: sternites or abdominal plates: d S-2 to d S-5: posterior doublures of sternites. ×1.

7—Restoration of the ventral side of the male mesosoma and first tergite of metasoma.

8—"Pretelson," or twelfth tergite, terminal spike, and "post-telsonic" structure. ×1. Compare Pl. 41, figs. 2,4.

9—Details of segmentation of "post-telsonic" structure. ×4. Compare Pl. 41, figs. 5,6.

10—Elongated scales of tergites.

and the scales are darker brown than the rest of the integument. The legs are dark brown, with black-tipped scales as in the tergites, and the spines of the leg grade from dark brown to black at the tips. The scales of the swimming leg are similar but the flattened elongated scales surrounding the paddle grade into black. The spines at the distal end are also black. The rest of the swimming leg is brown in color. The gnathobase is entirely black, whereas the coxae of the walking legs are light brown with darker brown scales. The telson is entirely black, contrasting greatly with the adjacent brown tergite. The coloration of *Carcinosoma newlini* is overall much like *Megalograptus ohioensis* but there are several important differences, much as occur in the various forms of living scorpions.

MEASUREMENTS OF SPECIMEN:

Prosoma:

Width at base:	73.2 mm.
Width behind eyes:	41.0 mm.
Length:	51.6 mm.

Lateral eyes:

Length:	12.0 mm.
Width:	8.8 mm.

Located on prosoma:

From anterior margin:	2.0 mm.
From posterior margin:	41.1 mm.
From lateral margin:	0.0 mm.

Mesosoma and metasoma:

	Length of tergites:	Posterior width of tergites:
1	8.2 mm.	84.0 mm.
2	14.5 mm.	100.0 mm.
3	14.5 mm.	110.0 mm.
4	14.5 mm.	114.0 mm.
5	14.5 mm. (est.)	99.5 mm.
6	14.5 mm. (est.)	90.5 mm.
7	11.5 mm. (est.)	59.0 mm.
8	21.5 mm.	45.0 mm.
9	28.3 mm.	42.5 mm.
10	32.4 mm.	41.0 mm.
11	49.1 mm.	38.0 mm.
12	54.0 mm.	26.0 mm.

Terminal spike:

Length:	68.0 mm.
Width at base:	22.0 mm.

Length of "post-telson": 15.2 mm.

Underside:

	Length	Posterior width:
Operculum	32.8 mm.	99.6 mm.
Sternite		
No. 1	15.0 mm.	112.5 mm.
No. 2	17.0 mm.	112.5 mm.
No. 3	15.6 mm.	97.5 mm.
No. 4	13.0 mm.	85.0 mm.
Tergite 7 (ventral)	11.5 mm.	59.0 mm.

Remarks.—The restorations given on Pls. 42,43 are based mainly on the specimen described above. The chelicerae, coxa of the swimming legs and metasoma are mostly unknown in this species. Otherwise, the restorations summarize our present knowledge of the species.

Horizon and Locality.—Silurian, Kokomo dolomite at Kokomo, Indiana.

Depository.—American Museum of Natural History, acc. #502.

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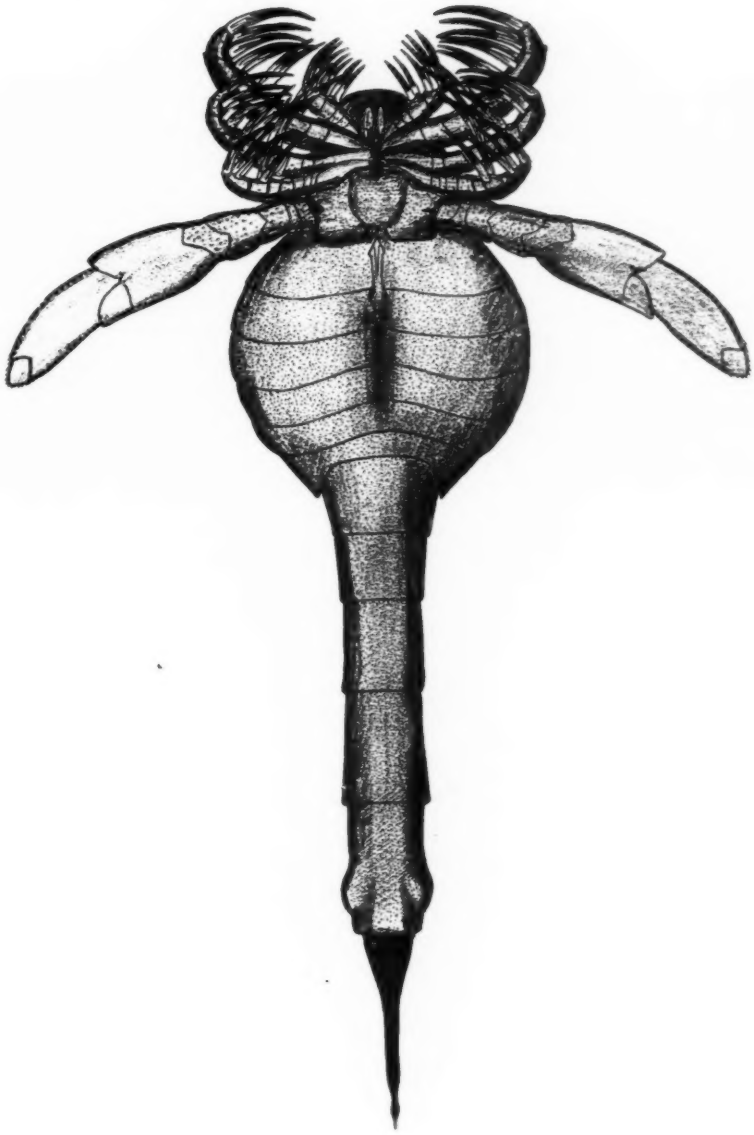
EXPLANATION OF PLATE 43

Ventral aspect of *Carcinosoma newlini* (Claypole), Silurian, Indiana, ×1/6.



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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 304–311, 2 TEXT-FIGS., MARCH 1958

RUSSIAN FUSULINID GENERA

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ABSTRACT—Eleven fusulinid genera, *Aljutovella*, *Armenia*, *Dagmarella*, *Eofusulina*, *Eostaffella*, *Dutkevichella*, *Hemifusulina*, *Parastaffella*, *Paraverbeekina*, *Putrella*, *Orientoschwagerina* and the subgenus *Eofusulina* (*Paraeofusulina*) are reported from Russian literature. The type species, age, reference, and remarks where appropriate are listed for each genus.

DURING the last ten years possibly as many as forty genera of fusulinids have been proposed by Russian authors. Thompson (1948 and 1954) reviewed the genera *Profusulinella* Rauser and Beljaev, *Rugosofusulina* Rauser, *Daixina* Rozovskaya, *Protriticites* Putrja and Rozovskaya's subdivision of *Triticites* into the subgenera *Rauserites*, *Jigulites* and *Montiparus*. Many genera, however, remain unmentioned in English language literature. The purpose of this note is to make available a paraphrased form of the Russian diagnosis and other pertinent information concerning some of these less well known genera.

FAMILY RELATIONSHIPS

M.-Maclay (1953) discusses the systematics of the family Fusulinidae Möller in which he recognizes seven subfamilies including the subfamily Polydiexodininae M.-Maclay, 1947. This subfamily was proposed to include schwagerinids with an elongate subcylindrical shell and cuniculi. Two genera are included, *Parafusulina* and *Polydiexodina*. One objection is that it does not seem to include the species of *Parafusulina* with a fuisform to fusiform elongate shell such as *P. schucherti* Dunbar & Skinner, and a second might be that the characters upon which the group is based are not as fundamental as those of the other subfamilies in the present classification.

Rauser & Rozovskaya (1955) propose to raise the Fusulinidae to a superfamily with three families, the Staffellidae, Fusulinidae and Schwagerinidae. Although the idea is not new it does afford a ready solution to many problems of fusulinid classification. Nevertheless, a superfamily is probably not warranted when the fusulinids are viewed in relation to the order Foraminifera.

GENERIC DIAGNOSES

Genera are assigned to the subfamilies listed by Thompson (1954, p. 6) wherever possible.

Subfamily OZAWAINELLINAE Thompson & Foster, 1937

Genus *Eostaffella* Rauser, 1948

Text-fig. 1—5,6

Reference.—Rauser 1948, p. 15–16 (diagnosis and type *fide* Ganelina, 1956 and Putrja, 1956).

Type species.—*Esotaffella parastruvei* Rauser, 1948, p. 15–16, Pl. 3, figs. 16–18.

Diagnosis.—Small to medium shell, involute, spirally coiled with a lenticular to spherical shape and compressed sides. The first volution sometimes has an endothyrid coil. The walls are calcareous, thin, obscure or they consist of three layers, a distinct tectum and an inner and outer tectorium. The septa are plain. Secondary deposits consist of irregularly occurring parachomata or chomata.

Age.—Lower Carboniferous (Viséan) to Permian.

Remarks.—Rauser & Rozovskaya (1955) synonymize *Paramillerella* Thompson with *Eostaffella*. Although *Eostaffella* clearly has priority over *Paramillerella*, M.-Maclay (1949) refers a specimen of *Millerella marbelensis* to *Eostaffella* which is confusing. *M. marbelensis* is the genotype of *Millerella* and as such is not referable to *Paramillerella* so there is some doubt as to whether *Esotaffella* and *Paramillerella* encompass the same concept.

Subfamily STAFFELLININAE
M.-Maclay, 1949

Genus PARASTAFFELLA Rauser, 1948
Text-fig. 2—5

Reference.—Rauser, 1948 (*fide* Ganelina, 1956).

Type species.—*Fusulinella struvei* Möller, 1880, p. 31–36, Pl. 5, fig. 4.

Diagnosis.—The shell is lenticular or subspheroidal and is compressed along the axis. It is usually involute or seldom evolute in the last volutions. An endothyrid coil is not observed. Dimensions of the shell range from small to medium. The wall is light gray and consists of four layers, a tectum, diaphanotheca, and an inner and outer tectorium. The septa are plain. Accessory deposits in the form of chomata or pseudochomata are not uniformly observed.

Age.—Lower Carboniferous (Viséan) to Permian.

Remarks.—Rauser & Rozovskaya (1955) synonymize *Parastaffella* with *Pseudoendothyra* Mikhailow. The description of the latter genus was not found.

Subfamily FUSULININAE Rhumbler, 1895

Genus ALJUTOVELLA Rauser, 1951
Text-fig. 1—3

Reference.—Rauser, 1951, p. 193, pl. 22, figs. 1,2 (*fide* Putrja, 1956).

Type species.—*Profusulinella aljutovica* Rauser, 1938, p. 87–89, pl. 1. fig. 10.

Diagnosis.—The shell has a shortened fusiform to subcylindrical shape and medium dimensions. The inner one to one and a-half volutions sometimes have endothyrid coiling. The wall is of three layers, a diaphanotheca is in addition, sometimes present in the outer volutions. The weak septal fluting is restricted to the axial region and the poles of the shell. Chomata are well developed. The tunnel is simple.

Age.—Lower part of the middle Carboniferous.

Discussion.—Species referred to *Aljutovella* include *Fusulinella? serotina* Thompson.

Genus DAGMARELLA Solovieva, 1955
Text-fig. 1—7

Reference.—Solovieva, 1955, p. 945–946.

Type species.—*Dagmarella prima* Solovieva, 1955, p. 945–946, fig. 1.

Diagnosis.—The shell is small to moderate in size, spirally coiled, shortened rhomboidal to elongate fuisform with bulky proportions. Septa are numerous, plain in the inner volutions and weakly fluted along the whole length of the shell in the outer one to two volutions. The wall has three layers, a tectum, protheca and outer tectorium. The inner chambers are covered with an extraordinarily heavy layer of inner tectorium.

Age.—Carboniferous (Moscovian). Nura-Tau and Aristan-Tau mountains, Kyzyl Kum, middle Carboniferous Verei and Kashir horizons.

Discussion.—Species referred to *Dagmarella* include *D. gephyrea* Dunbar & Henbest, *D. cadyi* Dunbar & Henbest, and *D. iowensis* Thompson. The genus is present in the Tian-shan, Urals, southeastern Russian platform and North America. *Dagmarella* is intermediate among *Profusulinella*, *Fusulina*, and *Fusulinella*. The three layered wall of the early Moscovian representatives and the lack of septal fluting in the early ontogenetic stages indicate a close genetic relationship to *Profusulinella*. The diaphanotheca in the late Moscovian forms of *Dagmarella* together with massive inner chambers relate it to *Fusulina*. The strong, deep fluting of the latter distinguishes it from *Dagmarella* whose fluting is not deep and present in only the last one to two volutions.

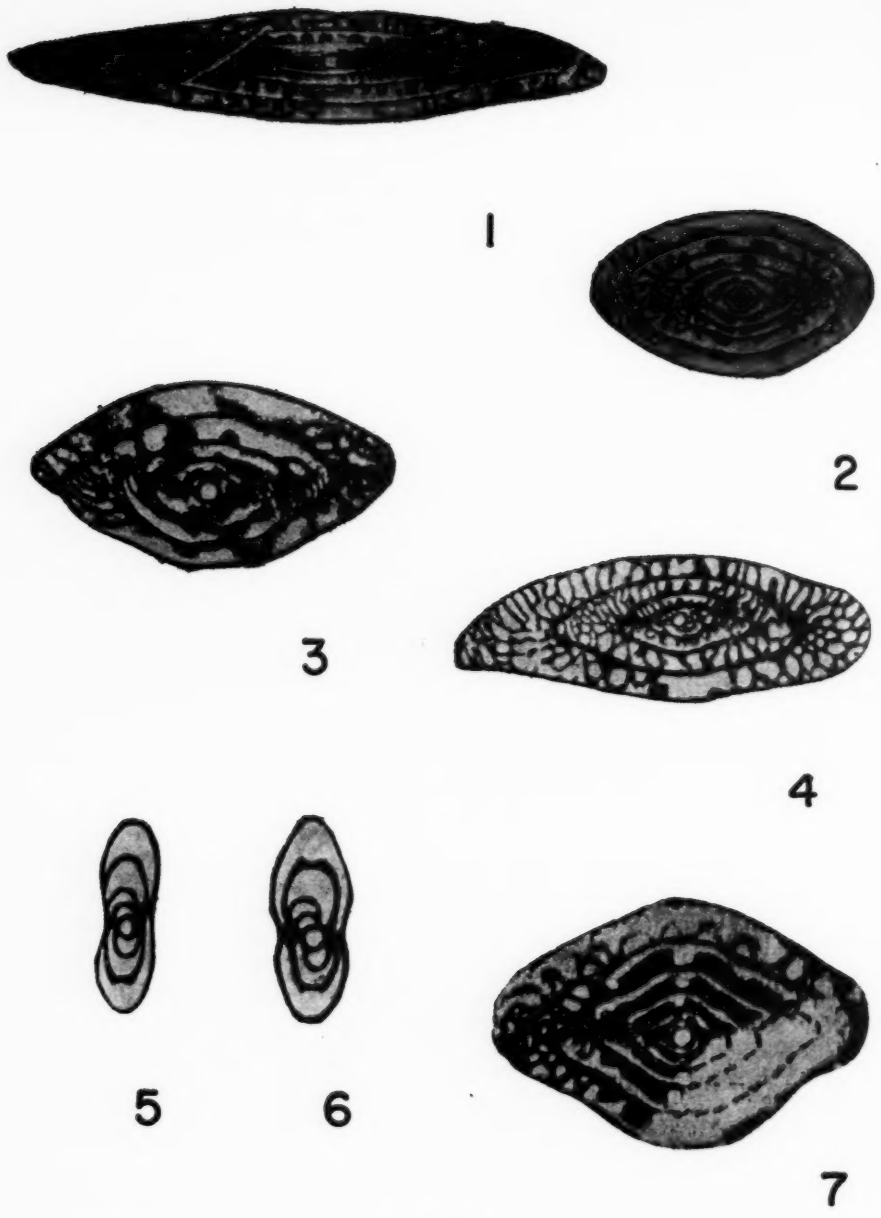
Genus DUTKEVICHELLA Putrja, 1956
Text-fig. 1—2

Reference.—Putrja, 1956, p. 460–61, pl. 16, fig. 2.

Type species.—*Fusulina dutkevichi* Putrja, 1937, p. 68–70, pl. 2, fig. 18.

Diagnosis.—The shell is small to large, almost spheroidal to subcylindrical in shape and varies little along the volution. The wall is thin and in the early chambers is weakly differentiated. In the outer ones it consists of a tectum, diaphanotheca, and two tectoria. The septa are moderately and regularly fluted. The fluting is more intense in the axial region of the outer volutions and less intense in the inner ones. Chomata occur irregularly and are subquadrate in shape. The tunnel is plain.

Age.—Middle Carboniferous (Moscovian).



TEXT-FIG. *1*

1—Paraeofusulina trianguliformis Putrja, axial section ×15 of the original figured specimen of the subgenotype, after Putrja, 1956, pl. 15, fig. 7.

2—Dutkevichella dutkevichi Putrja, axial section ×15 of the original figured specimen of the genotype, after Putrja, 1956, pl. 16, fig. 2.

3—Aljutovella aljutovica Rauser, axial section ×30 of the genotype, after Putrja, 1956, pl. 8, fig. 7.

4—Putrella Rauser, an axial section ×15 of *Putrella gurovi* Putrja, 1956, pl. 17, fig. 7.

5,6—Eostaffella Rauser. *5*, An axial section ×135 of *Eostaffella compressa* Brazhnikova; *6*, an axial section ×135 of *Eostaffella depressa* Putrja, both after Putrja, 1956, pl. 3, figs. 1,4.

7—Dagmarella prima Solovieva, axial section, ×30, of the original figured specimen of the genotype, after Solovieva, 1955, p. 946, fig. 1.

Discussion.—*Dutkevichella* differs from the nearest genus *Hemifusulina* Möller in the structure of the walls. *Hemifusulina* has more complex walls consisting of a diaphanotheca and inner tectorium perforated by rather simple pores. *Dutkevichella* is referred to the Fusulininae and *Hemifusulina* to the "Triticitids." The different stratigraphic distribution likewise warrants the separation of the two genera.

Genus EOFUSULINA Rauser, 1951
Text-fig. 2—6

Reference.—Rauser, 1951 (*fide* Putrja, 1956).

Type species.—*Fusulina triangula* Rauser & Beljaev, 1936, pl. 2, fig. 8.

Diagnosis.—The shell has three to three and one-half volutions and is strongly elongate even in the first volution. The wall is very thin consisting of a tectum and a finely porous protheca. The proloculus is significantly large, (200–250 microns). Septa are highly and intensively fluted. Accessory deposits are frequently present in the axial region. Rudimentary chomata are present only in the early chambers. The tunnel is simple.

Age.—Predominantly lower part of the middle Carboniferous.

Genus EOFUSULINA Rauser, 1951
Subgenus PARAEOFUSULINA Putrja, 1956
Text-fig. 1—1

Reference.—Putrja, 1956, p. 458.

Type species.—*Paraeofusulina trianguliformis* Putrja, 1956, p. 458–59, pl. 15, figs. 7,8.

Diagnosis.—The shell is medium to large and even in the first volution is strongly elongate. The wall is thin, consisting of a single type of finely porous structure in the inner volutions and of a weakly differentiated structure in the outer ones. The septa are intensively and evenly fluted along the whole length of the shell forming arch shaped loops. Accessory deposits consist of axial filling and in the inner volutions of pseudochomata.

Age.—Upper part of the middle Carboniferous, eastern Donbas.

Discussion.—*Paraeofusulina* is distinguished from *Eofusulina* by its greater number of volutions (up to five), the narrow coiling, and singular character of the septal fluting.

Genus HEMIFUSULINA Möller, 1877
Text-fig. 2—7

Reference.—Rozovskaya, 1946, p. 557–560. figs. 2a,b.

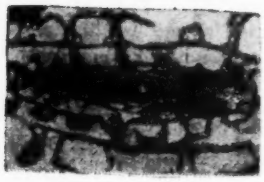
Type species.—*Hemifusulina bocki* Möller, 1878, p. 117–120, pl. 5, fig. 2; pl. 11, figs. 1–3.

Diagnosis.—Shell small, ovoid in shape, spiral closely coiled in the inner whorls, becombing higher and more uncoiled in the outer ones. Theca thin, of two layers, tectum and keriotheca. Trabecules wide, divided by very narrow pores. Septa from slightly to moderately folded, forming small arches, round and sharp and regularly situated. Chomata rounded, well developed in all whorls. Axial deposits lacking. Aperture (tunnel) singular, regularly situated.

Discussion.—Rozovskaya (1946) revived the genus *Hemifusulina* Möller as diagnosed above, and she referred it to the subfamily Schwagerininae. She distinguished *Hemifusulina* from *Fusulina* and *Triticites* on the the basis of wall structure. The wall of *Hemifusulina* differs from that of *Triticites* in the nature of the trabecules (the dark lines of the keriotheca) and the alveoli. Rauser & Rozovskaya (1955), however, place *Hemifusulina* in the Fusulininae because they feel it is more closely related to the "Triticitids" (*Pseudotriticites*, and *Putrella*) and to *Fusulina* than to *Triticites* proper. The wall of such genera as *Pseudotriticites* is illustrated by Thompson (1954) for *Protriticites* after an illustration by Rozovskaya (1950). It differs from the two-layered schwagerinid wall in having a diaphanotheca in the first three to four volutions and three layers, a keriotheca, a tectum, and a tectorium in the outer volutions. *Hemifusulina* is distinguished from *Fusulina* by the absence of a diaphanotheca in the outer volutions and from *Triticites* by the presence of branching alveoli.

Remarks.—Thompson (1948, p. 42–43, pl. 6, figs. 4,5) discusses the status of *Hemifusulina* Möller, apparently unaware of Rozovskaya's work, and clarifies the confusion concerning the type species *Hemifusulina bocki* (= *Fusulina minima* Schellwien) illustrating two figures of the holotype of *H. bocki* after Schellwien.

1



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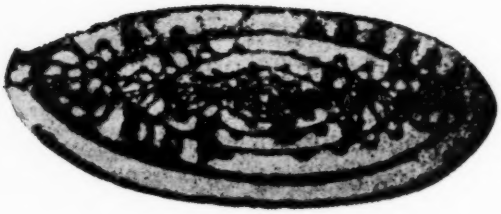

7

Genus PUTRELLA Rauser 1951
Text-fig. 1—4

Reference.—Rauser, 1951 (*fide* Putrja, 1956).

Type species.—*Pseudotriticites braznikovae* Putrja, 1948, p. 98–99, pl. 1, fig. 1.

Diagnosis.—The shell is inflated fusiform to subcylindrical in shape and rather large. The walls are significantly thick, consisting of two layers, a tectum and a wide, deeply porous keriotheca which is observable from the second volution outward. The wall of the inner one to two volutions sometimes has an indistinct diaphanotheca. The septa are highly and irregularly fluted. Chomata are present only in the early chambers and are weakly developed. The tunnel is simple.

Age.—Upper part of the middle and lower part of the upper Carboniferous.

Subfamily SCHWAGERININAE Dunbar & Henbest, 1930
Genus ORIENTOSCHWAGERINA M.-Maclay, 1955
Text-fig. 2—1,2

Reference.—M.-Maclay, 1955, p. 573–574.

Type species.—*Orientoschawgerina abichi* M.-Maclay, 1955, p. 574, figs. 1a,b.

Diagnosis.—The shell is large to medium size (5–8 mm. long), inflated fusiform with rather blunt poles. The first two to three volutions are very tightly coiled, the succeeding are loosely coiled. The proloculus, as a rule, is very small (86 microns). The wall has three (?) layers including a keriotheca. In the early part of the shell the septa are unfluted. In the later part they are intensely and irregularly fluted. The tunnel is simple. Axial filling is sporadically present.

Discussion.—*Orientoschwagerina* is morphologically close to the genera *Paraschwagerina* and *Acervoschwagerina*. It is distinguished from these by the lack of septal fluting in the early whorls and the characteristic fluting in the late volutions. Septal fluting is at a stage between *Paraschwagerina* and *Acervoschwagerina* but the juvenarium of the three genera differ so that it is apparent that the ancestral forms were different. The three genera are considered homeomorphs. The genotype has eight to ten volutions, length 6.3–7.2 mm., width 1.45–1.75 mm.

Age.—Lower Permian, Transcaucasia.

Remarks.—Despite the emphasis on the distinctive characters of *Orientoschwagerina*, it is more appropriately regarded as a subgenus of *Paraschwagerina* when viewed in relation to schwagerinid classification as a whole.

Subfamily VERBEEKININAE Staff & Wedekind, 1910
Genus PARAVERBEEKINA M.-Maclay, 1955
Text-fig. 2—3

Reference.—M.-Maclay, 1955, p. 574–575.

Type species.—*Paraverbeekina pontica* M.-Maclay, 1955, p. 574–575, fig. 1v.

Diagnosis.—The shell is large or small and inflated fusiform to ellipsoidal in shape. Inner endothyrid chambers are tightly coiled, but outer volutions are loosely coiled. The wall has three layers with a keriotheca. The septa are plain, the parachomata low, usually few in number and beginning with the fourth or fifth volution. The tunnel is multiple.

Age.—Upper Permian in the Crimea, Transcaucasia and Pamir.

←

TEXT-FIG. 2

1,2—*Orientoschwagerina abichi* M.-Maclay, *1*, axial section ×10 of the original figured specimen of the genotype; *2*, enlarged ×27 to show structure of inner chambers, after M.-Maclay, 1954, p. 574, figs. 1a,b.

3—*Paraverbeekina pontica* M.-Maclay, axial section ×10 of the original figured specimen of the genotype, after M.-Maclay 1954, p. 574, fig. 1v.

4—*Armenia karinae* M.-Maclay, axial section ×10 of the original figured specimen of the genotype, after M.Maclay, 1954, p. 574, fig. 1e.

5—*Parastaffella* Rauser. An axial section ×20 of *Parastaffella grandis* Putrja, 1956, pl. 4, fig. 10.

6—*Eofusulina triangula* Rauser and Beljaev, axial section ×10 of the original figured specimen of the genotype, after Rauser and Beljaev, 1936, pl. 2, fig. 8.

7—*Hemifusulina bocki* Möller, axial section ×30 of the genotype after Rozovskaya, 1946, p. 560, fig. 2b

Discussion.—Species referred to this genus include *P. taurica* (Toumanskaya). *Paraverbeekina* is related to *Verbeekina* Staff. The latter has a globular shell and the relationship of width to length is close to 1:1. In *Paraverbeekina*, on the other hand, the length is significantly greater than the width so that the relationship of width to length is nearer 1:1.25–1.5. In addition, *Verbeekina* is characterized by equal coiling of the shell so that the height of the chambers increases slowly in contrast to *Paraverbeekina* which has loose coiling in the late chambers. Some species of *Paraverbeekina* are close to species of *Misellina* Schenck & Thompson. The latter has massive parachomata which distinguish it from *Paraverbeekina*.

Genus ARMENIA M.-Maclay, 1955
Text-fig. 2—4

Reference.—M.-Maclay, 1955, p. 576.

Type species.—*Armenia karinae* M.-Maclay, 1955, p. 576, fig. 1e.

Diagnosis.—Shell medium size, inflated ellipsoidal to almost globular with a ratio of length to diameter of 1:1–1:1.25. The coiling is proportionally equal in both directions. The inner volutions are globular, few are compressed along the axis, and the latter volutions are ellipsoidal. The proloculus is very small. The wall is of three layers with a keriotheca. In the outermost volutions there are a few spiral septula which are joined to the parachomata. The parachomata are well developed, numerous, and similar in form to those of the genus *Misellina*. They are present in all volutions except the first two. There are multiple tunnels.

Age.—Upper Permian Transcaucasia, and lower and upper Permian Transcaucasia and Pamir.

Discussion.—There are similarities with the genus *Cancellina* Hayden. *Armenia* is easily distinguished from *Cancellina*, however, by the form of the shell, the low parachomata, weak development of the spiral septula and the structure of the walls. In *Armenia* the walls are almost like those of *Misellina* and *Verbeekina* and unlike the neoschwagerinid wall of *Cancellina*. *Armenia* is easily distinguished from *Misellina* by its development of spiral septula and the globular shape of the shell. The spiral septula relate *Armenia* to the neoschwagerinids but the character of the parachomata and structure of the wall are quite close to the verbeekinids. It represents an intermediate stage of evolution between these groups.

OTHER GENERA

There are another dozen less well known genera which are not treated in detail here. Information is available on some of these but others represent only names taken from stratigraphic papers. Three genera on which information is available are *Ussuriella*, *Monodiexodina* and *Pseudoyabeina*.

USSURIELLA Sosnina, 1956

Reference.—Sosnina, 1956, p. 21–24.

Type species.—*Ussuriella ussurica* Sosnina, 1956, p. 22–24, pl. 4, figs. 1–6.

This genus is found in the upper Permian of Asia. According to Rauser & Rosovskaya (1955) *Ussuriella* belongs in the subfamily Ozawainellinae. Sosnina refers *Endothyra*? sp. Thompson and Miller (1935, pl. 79, figs. 8,9) to this new genus.

MONODIEXODINA Sosnina, 1956

Reference.—Sosnina, 1956, p. 24–29, pl. 5, pl. 6, figs. 2–5, pl. 7, fig. 1.

Type species.—*Fusulina wanneri* (Schubert) var. *sutschanica* Dutkevich 1934.

This genus is found in Asia in the upper Permian and possibly in the lower Permian on the island of Timor. *Parafusulina wanneri* (Schubert) Thompson (1949) is referred to *Monodiexodina*. The genus belongs in the subfamily Schwagerininae Dunbar & Henbest, or if accepted, in the subfamily Polydiexodininae M.-Maclay.

PSEUDOYABEINA Toumanskaya, 1954

Reference.—Toumanskaya, 1954, p. 98.

Type species.—*Yabeina lantschichensis* Toumanskaya.

This genus occurs in the upper Permian of Tethys. It is probably referable to the subfamily Neoschwagerininae Dunbar & Condra.

Additional genera are mentioned by Rauser & Rozovskaya (1955) for which no diagnoses or type descriptions were found.

Staffellinae.—*Pseudoendothyra* Mikhailow.

Ozawainellinae.—*Novella*, *Seminovella*, *Parareichelina*, *Eozawainella*.

Schubertellininae.—Lantschichites Toumanskaya, *Tawaizites* Toumanskaya (a junior synonym of *Minojapanella* Fujimoto & Kanuma).

Fusulininae.—Parawedekinellina, Obsoletes, Verella.

Unclassified.—Sichotonella Toumanskaya.

M.-Maclay (1953) lists the genera *Carina* in the Staffellinae, *Armeniella* in the Schubertellininae and *Orientella* in the Schwagerininae.

In a stratigraphic paper on Permian fusulinids he (M.-Maclay, 1955) mentions several genera belonging to the Schwagerininae.

Robustoschwagerina M.-Maclay (?) with the type species *Pseudoschwagerina tumida* Likarev.

Rugoschwagerina M.-Maclay (?) which includes the species *Pseudoschwagerina yabei* (Staff).

Sphaeroschwagerina M.-Maclay (?) with the type species *Schwagerina princeps* Schellwien, 1898.

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CAMBRIAN BIOSTRATIGRAPHY IN NORTH AMERICA

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ABSTRACT—The biostratigraphic column of the Cambrian is based upon the ranges of trilobites. Brachiopods have received a limited use in the Late Cambrian. Faunal units based on four different kinds of evidence have been utilized. Each set of units must be kept distinct. 1) Local maximum abundance of a genus or species, and 2) local time range of a genus or species are important locally but have only limited areal value for correlation. 3) Range of a characteristic faunal assemblage, determined by the median level of overlap of the biozones of many genera, has a greater time range and wider geographic application. The Cambrian *faunizones* are based on such distinct assemblages, named, for convenience, from one or two of the common genera. 4) The ranges of trilobite families have been utilized as a means of effecting intercontinental correlations across biofacies barriers.

Three biofacies realms are recognized in the northern hemisphere from the Pacific through northwestern Europe. They are oriented concentrically around the ancient continent of Laurentia. They are designated as the *cratonic* (*shallow shelf*) *biofacies realm*, comprising the shelf and unstable shelf areas bordering Laurentia; and the extra-cratonic realms divided into the *intermediate biofacies realm*, coinciding with the bordering miogeosynclinal areas, and the *extracratonic* (*euxinic*) *biofacies realm*, coinciding with the outer mobile belts encircling the craton. The ecological conditions characterizing each biofacies are briefly considered.

Cambrian faunal zones, especially of the Late Cambrian, have appeared unique in their wide distribution of an orderly succession of faunal units thought of as assemblages of vertically well-segregated genera. The ranges of all the recognized genera are charted and the amount of overlap in the ranges of characteristic trilobite genera of the assemblages is indicated. From the late Lower Cambrian, through the Middle Cambrian and most of the Dresbachian, the assemblages of the faunizones show a normal evolutionary development averaging a 40% overlap of genera and with no sharp faunal changes. During this time the ecologic conditions of each biofacies remained stable permitting an orderly development of their respective characteristic assemblages. It is only in the late Dresbachian and Franconian that assemblages of vertically well-segregated genera bounded by sharp faunal breaks appear in the column. This phenomenon was caused by pronounced and relatively sudden changes of ecologic conditions within the intermediate and cratonic biofacies realms. In the cratonic realm the ecologic changes at one level coincided with widespread tectonism effecting a very pronounced hiatus. As one passes from the cratonic into and across the intermediate realm, the distinctness of the cratonic assemblages blurs, until exteriorly only much broader faunizones containing 35–50% non-cratonic genera can be recognized. The extreme is reached in the extracratonic euxinic realm where the assemblages of an entire period are comprised of the slowly evolving genera of a very few families.

The name, *Dunderbergia* faunizone, is proposed for the distinct assemblage between the *Aphelaspis* and *Elvinia* zones. The Dresbachian stage is restricted to the *Cedaria-Crepicephalus* faunizones as being more consistent with conditions in the Croixan type area. A new stage comprising the *Aphelaspis* and *Dunderbergia* faunizones is placed between the Dresbachian and Franconian. The name and type section of this stage are to be chosen later from the Great Basin region where the most complete stratigraphic succession and faunal assemblages of this stage are known to occur.

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INTRODUCTION

THE Cambrian biostratigraphic column has been developed upon the ranges of trilobite genera and all study to date has verified the value of this group. Trilobita far surpass in numbers the other Cambrian fossils. During the past 60 years an appreciable amount of descriptive work has been done, with the stratigraphic relationships of the different genera receiving more and more attention in the past twenty-five years.

The value of the other fossil phyla and genera in the Cambrian appears to be severely limited by (1) their rare and sporadic occurrence, (2) the absence of any significant structural features in the shell, or (3) the primitive, generalized condition of the phylum as a whole, as, for example, the Brachiopoda of which some inarticulate genera apparently range through the entire period. Specialists can find no distinctive changes in these shells. But careful study of some Upper Cambrian brachiopod genera and species has revealed sufficient specialization to give them a limited biostratigraphic use. Zones based upon them are much broader than those developed upon the trilobites.

The Cambrian biostratigraphic units of the North American continent, especially those of the Late Cambrian, have appeared unique in their wide distribution of an orderly succession of faunal zones which have usually been thought of as assemblages of vertically well-segregated genera. Several factors which deserve critical evaluation have contributed to this idea.

(1) The simplicity of the faunal assemblage—only one group of animals is being considered, and as a group their evolutionary responses to environments should and do follow one type of pattern. As soon as the Brachiopoda are considered in the Late Cambrian a different type of environmental response pattern appears which is reflected by a different zonation pattern.

(2) During the Cambrian, although there were extensive areas of clear shallow seas, there was no development of the true reef habitat—a bioherm—which can produce its own environmental regimes. In the Early Cambrian the Archaeocyathids produced

extensive reef-like structures on shelf and miogeosynclinal sites, but no special adaptations to a reef environment can be noted among the associated trilobites or brachiopods. There were apparently only a few very widespread environmental regimes—biofacies—whose environmental patterns were basically controlled by their geographic position and their tectonic responses. The trilobites, as mobile larvae and vagrant benthos adults, could attain a wide geographic distribution within any one biofacies. All Arthropoda appear more tolerant of salinity variations than do other phyla.

(3) Most studies have been provincial—the zones were based on the ranges of genera within one well-studied area; then scattered and fragmentary collections from other areas have been fitted into the local sequence. Although many Cordilleran faunas remain to be described, it is now evident that more complexity and variation in generic ranges exists than has been indicated. The limited knowledge of the faunas has tended to give an over-simplification of the assemblages.

(4) The studies have been limited geographically—the best known Cambrian faunas are those which inhabited the shelf areas bordering the southern shores of Laurentia. As research expands into other paleogeographic sites, application of the standard zonation becomes increasingly difficult. Of the extracratonic areas, the eugeosyncline with its markedly different sedimentation, tectonism and environmental conditions shows the least faunal similarities. However, the broad miogeosynclines of the Cordilleran region provided a convenient transitional belt toward the cratonic regime. (All these belts moved eastward and broadened progressively through the Cambrian and into the basal Ordovician.)

ACKNOWLEDGEMENTS

In the extensive compilations of faunal assemblages required for this paper the authors have been able to draw freely upon both the published and unpublished work of many paleontologists and stratigraphers now actively working on Cambrian faunas. In the bibliography only the more comprehensive titles can be listed. But here they wish to express their sincere thanks to and heartfelt appreciation of the many hours of profitable discussions and the valuable unpublished data which were most generously offered by Robert Berg, W. C. Bell, N. C. Denson, D. C. Duncan, H. L. Ellinwood, O. W. Feniak, R. H. Flower, M. N. Gilman, Richard Grant, B. F. Howell, V. E. Kurtz, C. A. Nelson, A. R. Palmer, G. O. Raasch, Franco Rasetti, A. B. Shaw and Donald Winston.

BIOFACIES REALMS

The compilation of the Cambrian and basal Ordovician trilobite assemblages for the charts reveals the presence of three widespread biofacies realms in the northern hemisphere recognizable at least from the western Pacific eastward through northern Europe. The authors have chosen familiar generalized terms by which to designate these realms. The terms craton and extracraton are used because there appears to be a definite relationship between these biofacies realms and the geographic position and tectonic control implied by these terms.

The writers are aware that a preferable approach would be to characterize the biofacies realm directly with environmental terminology, but such is not now possible because of limited knowledge of the ecology of early Paleozoic faunas. In a general way the coincidence of the biofacies belts with previously recognized tectonic and geographic elements of North America is demonstrable, but exactly how the environments resulting in the biofacies are related to tectonic position is far from clear. Conjectural descriptions of these early Paleozoic environments are given below following an outline of the terminology used.

Tectonic:	cratonic	extracratonic	
		miogeosynclinal	eugeosynclinal
Environmental	shallow shelf	intermediate	euxinic basin

The biofacies realm of the craton comprises the stable shelf and unstable shelf areas surrounding the continental mass of Laurentia. Outcrop and subsurface Cambrian sequences studied to date classify predominately as shelf and unstable shelf types. The subsurface sequence of southern Illinois is the only known possible representative of an intracratonic basin. The controlling ecologic factors show an essential unity throughout the realm although the biofacies may extend thousands of miles linearly. These factors were: (1) variable salinities of the sea water; (2) marked diurnal and seasonal fluctuations of water temperatures and air temperatures; (3) turbulence—waves and currents producing well-oxygenated water; (4) variability of sea bottom conditions and variable opacity of overlying waters; (5) prevalence of shallow water depths—low pressures. The sediments suggest that extreme shallowness was frequent, possibly in general from zero to 50 feet. (6) Subdued tectonism—subsidences and emergences slight to very moderate, low extensive islands or tidal flats sporadically exposed, innumerable diastems and disconformities, the sea floor often attaining the profile of equilibrium. (7) Domination of the realm by the continental land mass—the fresh water of the land rivers alter the salinity of the sea water, furnish a large and distinctive supply of organic and inorganic nutrients from the continent as well as most of the clastic detritus reaching the realm. The keynote of the cratonic biofacies is instability—change. The faunas characteristic of this biofacies were termed Pacific province assemblages as they were first described by Walcott in part from the Cordilleran region. In this paper they are termed cratonic (shallow shelf) biofacies.

In the extracratonic sites two biofacies realms are recognized. The intermediate biofacies realm corresponds rather closely to miogeosynclinal sites and forms a transitional facies between the other two realms. Its quite slow, even though steady, subsidence has imparted to its basic ecologic factors many similarities with those of the unstable shelf areas of the craton and consequently the faunal assemblages of the two realms are closely related. The expanse of the open sea over the miogeosynclinal sites was more unbroken than over the shelf areas, yet extensive carbonate shoals are known to have built up time and again to sea level. The ecologic factors are still characterized by variability but of a more tempered nature than that of the cratonic realm. (1) The salinity of the sea water varied, but the fresh and brackish water elements were eliminated, (2) the air temperatures were more equitable but water temperatures still fluctuated over the shoals, and between shoals and deeper water areas, (3) turbulence of water was common, but quieter waters occurred in the deeper sites, (4) sea bottom conditions and opacity of water remained variable, (5) shallow water depths and low pressures were common—the lithogenesis of the carbonate sequences of the miogeosynclinal sites indicates that the depths of deposition varied from shoals to moderately deep water with greater depths present sporadically and more frequently along the outer half of the area, (6) tectonism moderate—subsidence slow but persistent, usually but not always keeping pace with the rate of deposition, islands rare, and few disconformities but diastems often representing failure of sedimentation, (7) the continental land mass is no longer dominant though sporadically it makes its influence felt. At times of maximum influx of clastics from the continent, the finer detritus and accompanying chemical nutrients are carried by currents past the unstable shelf and into the intermediate realm. But the more removed sites appear to derive their very small amounts of clastics only from widely scattered islands. The faunas of the intermediate biofacies are composed predominately of genera of the cratonic shallow shelf assemblages, but 20 to 25 percent of the genera are typically non-cratonic. This biofacies is partly known from exotic boulders found in overlying Ordovician graptolitic shales (Lévis and Marathon regions)—strata derived from the intermediate biofacies realm and incorporated in euxinic basinal deposits in extracratonic areas of later time.

The extracratonic euxinic realm represents a biofacies found in all sites farthest removed from the continental land masses. This biofacies is characterized by distinctive faunal assemblages very different from those of the cratonic realm and partially dif-

ferentiated from those of the intermediate realm. The keynote of this biofacies is stability—monotony of environment. The faunas of this biofacies were termed the Atlantic province or Acado-Baltic assemblages as they were first described from the countries bordering both sides of the North Atlantic Ocean. Recent work has revealed the widespread presence of elements of these assemblages throughout the far western Cordilleran region and in the Marathon uplift of Texas in North America and in the Argentine in South America. The sections containing these assemblages show many significant lithogenetic similarities which indicate that the basic ecologic factors controlling this biofacies were fundamentally different from those of the other two realms. The sites lay within or adjacent to tectonically mobile belts and derived their clastic sediments largely from islands rather than continental masses. Although the eugeosynclinal sites are, in many places, defined by thick sections of volcanics and graywacke sandstone, apparently in the mildly tectonic Cambrian silled and partially starved shallow basins existed in extreme extracratonic positions. That notably thinner sections *may* be associated with dark argillite, graptolitic strata has been pointed out by P. B. King (1951, p. 150) and Wilson (1954b, p. 2472–74 and 1957, p. 335–336). These conditions in the Cambro-Ordovician are widely distributed in the world's geosynclinal belts farthest removed from the cratons.

A most significant feature of this realm may have been its control by the open ocean: (1) the salinity of the water was normal and essentially constant; (2) the air temperature and the water temperature were equitable, subject only to small, slow seasonal changes and the established movement of ocean currents; (3) turbulent water was restricted to the littoral zones, narrow tidal flats and shallows around the islands —quiet water dominated the sea bottoms and frequently developed stagnant layers in semi-restricted silled basins; (4) soft mud bottoms were prevalent and it is believed that the water above the bottom was constantly murky as the fine clay particles were stirred into suspension by movements of the benthos; (5) shallow depths of restricted widths were present around the islands—but the areas of greater depths, 400 to 600 or more feet may have been much more abundant and readily available to benthos adjusted to increasing pressures and lack of oxygen in the silled basins; (6) active tectonism—subsidence alternating with emergence around the islands, disconformities numerous; rapid subsidence of the adjoining ocean bottoms which may or may not be accompanied by rapid deposition; numerous diastems resulting from slow and sporadic sedimentation, glauconite and phosphate nodules common—the sediment derived from the island areas was not enough to cover the widely submerged sea floor. (7) Dominance of the open ocean—the food supply based largely upon oceanic resources, planktonic plants and animals, local nekton and benthos; the amount of clastics dependent upon the tectonism of associated lands and conditions favoring a very limited development of carbonates. The main lithic types with fossils are dark shales and dark-gray to black limestones (in nodules or thin beds), in places with associated volcanics and dark cherts possibly derived from volcanic material. The continued sameness of the environment favored the development of a very few adapted stocks which maintained themselves for unusually long periods of time. The only ecological conjecture about the Cambro-Ordovician euxinic environment based on critical observation is that recently published by Henningsmoen (1957, p. 61–82) in connection with a study of the olenid trilobite stock, one of the groups uniquely adapted to this environment. He evokes such factors as turbid water, stagnant in poorly ventilated muddy basins on the shallow edges of the Baltic shield in describing olenid ecology.

THE FAUNAL UNITS

The Cambrian biostratigraphic column has been undergoing continuous correction and refinement. The standard faunal units used in this paper are not all the same as those on the 1944 Cambrian Correlation Chart (Howell, et al., 1944) as much additional information has been obtained in the past fifteen years. In developing the Cambrian faunal succession, researchers have utilized four approaches.

In all restricted areal studies (1) the local

maximum abundance and (2) the local time range of a genus or species may have important local value for correlating beds. The beds in which such genera or species occur are given their name and have been spoken of as "zones." These biostratigraphic units may be based on the *local* maximum abundance—or dominance because of size or morphology—of a single genus or species (or of a limited number of them). We term such a unit a *zonule*. For the assemblage of fossils obtained from a zonule we use the term *faunule*, following the practice of Rasetti (1951). Earlier attempts to extend these local zones for intracratonic correlation led to confusion. Association of the word *zone* with these local faunules has led many people unfamiliar with the details of Cambrian stratigraphy to confuse them with the standard interregional correlation units.

The local sequence of beds through which a particular locally significant genus or species ranges is a *teilzone*. As different areas were studied, certain local genera demonstrated a wider geographic occurrence than others and maintained their respective stratigraphic positions. A reasonable estimate of the total biostratigraphic span of a particular genus—its *biozone*—the sum total of its teilzones within the cratonic areas, was evolved. The names of these genera were used to refer to a particular intracratonic stratigraphic level. The close environmental control of the cratonic biofacies upon the evolution of these genera injects this limiting geographic factor into their biozones. Although many Cambrian trilobite genera were so controlled, some are known for which the biozones are not so limited. Because of the countless variations in local environments and sedimentation throughout so vast a region as the North American cratonic realm during the Cambrian, the teilzones vary markedly in thickness, and locally such widespread genera and species might be rare and inconspicuous at the position of their biozone.

(3) For intracratonic correlation the concept of stratigraphically significant assemblages of trilobite genera and species is used. We term the biostratigraphic span of such an assemblage—a *faunizone*. We infer its significance as a time rock unit from its widespread distribution and from the consistent stratigraphic position of many such units. *Zone* is frequently used in this sense also and is recommended terminology by Mallory and Wheeler (1957). Within such a unit is encompassed all or much of the biozone of each of the diagnostic genera. Practically this concept makes available a large number of biozones for intracratonic correlation. The limits of each particular biozone may be well within the time-rock span of the zone or may extend a short distance beyond the accepted boundaries of the faunal unit. The median level where most of the biozones overlap determines the characteristic faunal assemblage. The faunizones are named from one or several of the widespread genera, a) whose biozones fall wholly or largely within the time-rock span covered, or b) whose initial appearance and maximum abundance was during that span. Where a widespread subdivision of a standard faunizone is recognized, it is termed a *subzone*.

(4) A consideration of the vertical ranges of trilobite families is proving to be a means of effecting correlations across the major biofacies barriers which are encountered between the cratonic and extracratonic regions. The discovery and study of a few assemblages intermediate in geographic position and with some genera from each of the neighboring biofacies has been helpful. This method requires a thorough knowledge of all the assemblages involved and has yielded the best results for the Upper Cambrian to date. The movements of the families between the extracratonic and the cratonic regions was directed by pronounced biofacies changes upon the craton. Even in the more poorly known Early and Medial Cambrian assemblages significant trends are being revealed.

In the Lower and Middle Cambrian charts faunizones only are used. On the Upper Cambrian charts faunizones are used, and some zonules and teilzones from the Montana and the Texas sections, and from the Wisconsin standard section are shown. The ranges of all described Cambrian trilobite genera are tabulated, placing them in the most recent familial categories.

On the Lower and Middle Cambrian charts the faunal units appear as a succession of mixed assemblages with a few genera

of limited vertical range, a moderate number of wider vertical range and variable geographic occurrence, and a third small group of long vertical and wide geographic range. The limits of the faunizones are strongly influenced by the biozone limits of one or several genera widely distributed in the cratonic sites of deposition.

The Late Cambrian faunal units of North America have ranked with the Mesozoic ammonite and Late Paleozoic fusulinid zonations as among the most clearly applicable biostratigraphic systems in the world. This detailed zonation was developed upon the broad cratonic realm which extended from the Cordilleran area (Montana-Wyoming) through central United States (Croixan, Ozarks, Arbuckles, and Texas areas) eastward to the Appalachians (New York, Pennsylvania to Georgia). Eight standard faunizones can be recognized in the cratonic and intermediate realms. They comprise convenient groupings of the ranges of approximately 200 genera. The charts show that there are actually six more or less vertically distinct assemblages which have influenced the faunal units—*Cedaria-Crepicephalus*, *Aphelaspis-Dunderbergia*, *Elvinia*, *Conaspis*, *Ptychaspis-Prosaukia*, and *Saukia*. These six assemblages appear throughout both cratonic and intermediate realms in the same stratigraphic sequence and with consistent relation to certain widespread physical changes. At one position, between the *Aphelaspis* and *Elvinia* faunizones, widespread tectonic and physical reorientation accompanied the environmental changes and the *Dunderbergia* faunizone is wholly or in part missing. But in the few known intermediate assemblages a gradual transition between the three assemblages can be demonstrated. The essentially vertically segregated condition of these six Late Cambrian cratonic assemblages is unusual but real as very few overlapping genera are known. This phenomenon is attributed to the occurrence during the Late Cambrian of four relatively rapid and marked biofacies changes throughout the intermediate and cratonic realms.

LOWER CAMBRIAN BIOSTRATIGRAPHY

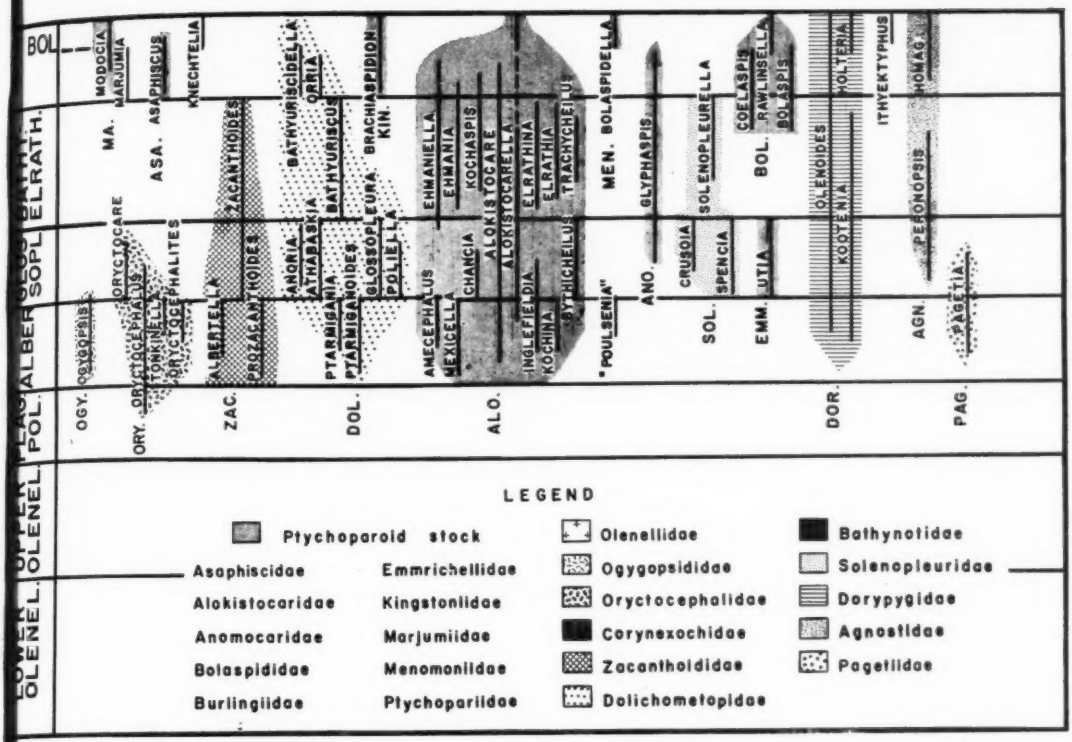
For both cratonic margin and extracratonic assemblages the Lower Cambrian has been considered to coincide with the biozone of the Olenellida. In the Acado-Baltic region three faunizones are recognized, spanning about the upper half of the epoch. For the North American shelf and miogeosynclinal areas only two faunizones are recognized, a lower in which the Olenellida are the only trilobites present, and an upper in which Olenellida are associated with primitive opisthoparian genera. In the Cordilleran region the shelf and miogeosynclinal areas are known to have been much narrower and lay much farther westward than later in the period, and the eugeosynclinal sites can no longer be positively identified. The archaeocyathids were adapted to the cratonic realm, but no biofacies preferences can be detected from the distribution of the other non-trilobite genera.

The generic distributions and family patterns on the charts (figs. 1–5) are interpreted as follows:

The Olenellida were world-wide in distribution and were apparently already an old stock before they acquired a preservable exoskeleton. *Olenellus*, *Fremontia*, *Wanneria* and *Paedeumias* had acquired a preference for the intermediate and shelf biofacies around Laurentia, and *Callavia*, *Holmia*, *Kjerulfia* and *Olenelloides* for the extracratonic—open ocean environment. *Nevadia* appears early in the Lower Cambrian in the Cordilleran region where it is associated with *Olenellus* and *Paedeumias* in westernmost miogeosynclinal sites. *Nevadella* appears in the later half of the epoch in the same sites and with the same associations. *Nevadia* and *Nevadella* have also been recorded from the Acado-Baltic province in late Lower Cambrian beds associated with *Callavia*. *Elliptocephala* was indigenous to a boundary biofacies adjoining the inner edge of the extracratonic euxinic realm in eastern North America, and since it is not known north of Massachusetts it is suspected of having southern origins.

A number of primitive opisthoparian families appear in the late Lower Cambrian. The generic and familial patterns on the charts suggest the probable indigenous sites of these groups.

The Ptychopariidae, Alokistocaridae, Zacanthoididae, Dolichometopidae and Bathynotidae originated in the cratonic margin



TEXT-FIG. *1*—Lower and Middle Cambrian Cordilleran Cratonic Realm.

biofacies along the north and northeastern coasts of Laurentia. These families are best represented here; certain genera (*Kochiella*) do not appear in the Cordilleran region until early Middle Cambrian; and the Bathynotidae are otherwise recorded only from Siberia. The assemblages of the southern miogeosynclinal and shelf areas on both sides of the continent, at this time and during the Middle Cambrian, seem to have been predominately composed of forms derived from this northern realm.

The Dorypygidae are also well represented in this cratonic margin biofacies, but it is believed that this family and the Pagetidae may actually have originated in a boundary biofacies developed along the outer edge of the intermediate realm. The Dorygypidae are represented in all biofacies realms, with one genus (*Kootenia*) in common. Both families are unusual in the fact that many of their genera show an easy tolerance of variable environmental conditions, accompanied by an extremely long vertical range and wide geographic distribution within the northern hemisphere. In the extracratonic euxinic assemblages the Pagetidae are represented by several different genera, and the Dorypygidae by two, with *Bonnaria* also occurring in the *Elliptocephala* fauna.

Three families, the Solenopleuridae, Oryctocephalidae and Agnostidae, each represented by one genus, make their initial appearance in the cratonic margin realm of eastern North America, yet in the Middle Cambrian all three families develop as characteristic groups of the extracratonic euxinic biofacies—the Solenopleuridae and Agnostidae being especially characteristic of this biofacies.

The families originating in the extracratonic euxinic biofacies fall into two groups, the normal trilobites—the Protolenidae, Antatlasidae, Paleolenidae and Elleipsocephalidae; and the blind trilobites, the

Conocoryphidae and Eodiscidae. The prominence of the Eodiscidae in the late Lower Cambrian assemblages of this biofacies and their persistence throughout the Middle Cambrian; and the conspicuous position of the Conocoryphidae in the Middle Cambrian assemblages is regarded as more than a coincidence. Some important ecologic factor in the extracratonic euxinic biofacies must have favored the blind condition. Among the normal trilobite families where eyes are present, features of carapace flattening are noticeable. The convexity of the glabella and the entire cephalon is low, and on many genera the cephalic furrows tend to obsolescence.

Three assemblages of mixed composition are known bordering the eastern shelf of Laurentia—the *Elliptocephala asaphoides* fauna of eastern New York, the Devils Cove fauna of Newfoundland and an assemblage in the Slakli series of Spitzbergen. *Elliptocephala* occurs only in the southernmost assemblage, *Callavia* appears in the Newfoundland fauna, and *Olenellus thompsoni* (a typical eastern shelf species) and *Nevadella* appear in Spitzbergen. The Eodiscidae are present in all three faunas.

Gross lithology per se was not an important ecologic factor in biofacies control. In eastern North America shelf assemblages are found in sandstone, dark brown to black-gray, calcareous sandy shales and shales, and pure or sandy limestones and dolomites. But in the cratonic margin realm the quartz sand and carbonate lithofacies are as common as the shale facies. In the Cordilleran region many of the late Lower Cambrian beds are the initial sands and shales of the transgressing seas; but farther west in miogeosynclinal sites carbonates become prominent. The extracratonic euxinic assemblages are found in sands, sandy shale, gray, green, purple and black siliceous shales, siltstones or claystones, and thin dark gray, argillaceous limestone beds, nodules and lenses. Graywackes occur in the sections in eastern New York and Vermont which carry the *Elliptocephala* fauna. Clastic rocks, particularly the fine-grained shales, dominate the sequences of the extracratonic euxinic biofacies. The carbonates are subordinate, usually quite impure, and of limited areal extent.

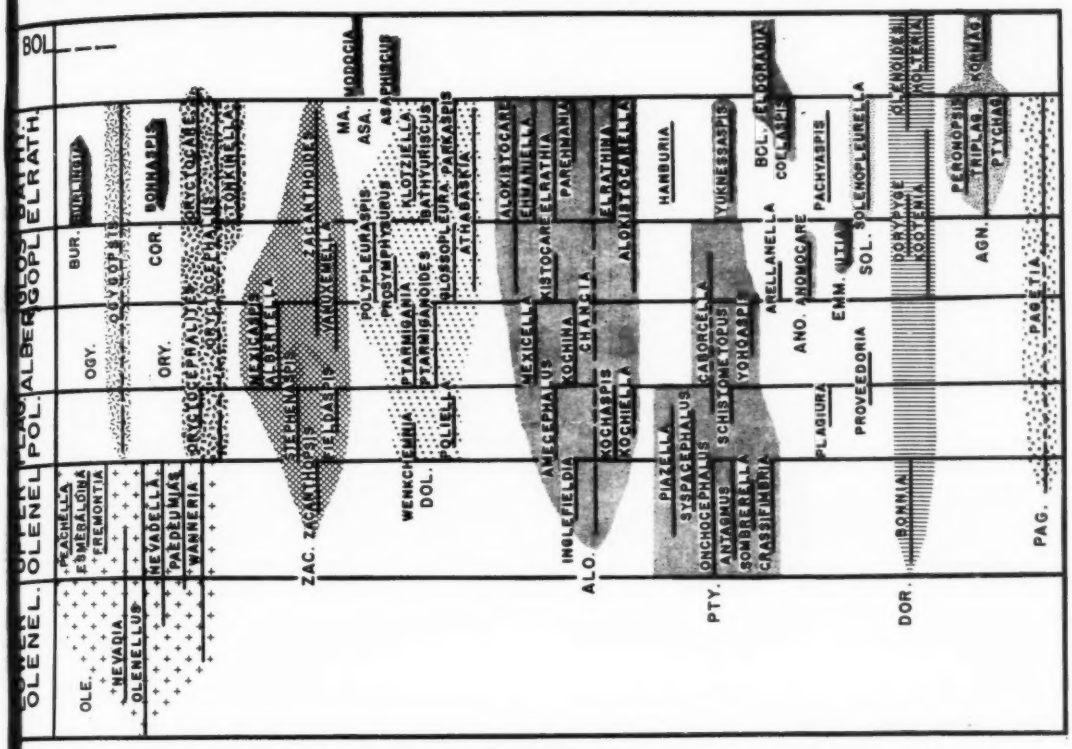
The correct correlation of the various assemblages furnishes a more accurate paleogeographic picture. Only extracratonic sites received sedimentation during the early half of the Lower Cambrian. These sites are now of interrupted and widely scattered occurrence, in southwestern North America, in Washington state, in Vermont and the southern Appalachians. Inundation of the cratonic sites around Laurentia dates from the late Lower Cambrian and coincides approximately with the subsidence of the Acado-Baltic extracratonic sites.

MIDDLE CAMBRIAN BIOSTRATIGRAPHY

During the Middle Cambrian both extracratonic and cratonic realms expanded eastward in the Cordilleran region. Typical eugeosynclinal lithofacies and biofacies are very poorly known, but faunal elements of this biofacies invaded the miogeosynclinal areas and can be traced eastward into southeast Idaho and north central Utah where a narrow southeast trending embayment, tectonically related to the miogeosyncline, abutted against the Uinta positive element. Figure 2 shows the assemblages of the intermediate biofacies, and figure 1 those of the cratonic realm. On the latter appear the extracratonic genera of this embayment, confined to the Spence shale and the Langston limestone.

The intermediate biofacies is characterized by 1) the presence of a number of noncratonic genera (20%), and 2) the occurrence of the earliest known Middle Cambrian assemblages—those of the *Plagiura-Poliella* faunizone. A familial continuity can be traced directly from the late Lower Cambrian primitive opisthoparia. In the cratonic realm on both sides of the continent there was no sedimentation at this time, and a pronounced break appears at this level. In the Cordilleran shelf sites the oldest assemblage belongs to the *Glossopleura* zone (with the exception of the Utah embayment). The abrupt appearance of the families in the cratonic realm reflects the late start in sedimentation rather than any evolutionary trend.

In the earliest Middle Cambrian five families from the northern cratonic realm appear in the Cordilleran region with the advancing seas, the Zacanthoididae, Dolichometopidae, Ptychopariidae, Alokisto-



TEXT-FIG. 2—Lower and Middle Cambrian Cordilleran Intermediate Realm Middle Cambrian—20% Non-cratonic; Lower Cambrian—10% Non-cratonic.

caridae and Oryctocephalidae. The Zacanthoididae reach their modest peak in the *Albertella* faunizone, and thereafter are represented only by *Zacanthoides*, persisting to the end of *Bathyuriscus-Elrathina* time. In the Ptychopariidae, the more primitive Antagminae die out rapidly, but only a few genera of the more advanced Ptychopariinae appear in the western miogeosynclinal sites. This subfamily has developed a strong preference for the extracratonic euxinic biofacies. The Dolichometopidae record a slow rise to a peak in the middle Middle Cambrian. In the miogeosynclinal sites they maintain their position from the *Glossopleura* faunizone through the *Bathyuriscus-Elrathina* faunizone, but in the cratonic sites they show a marked dislike of that environment during the latter time and are represented only by *Bathyuriscus*. The biozone of the family extends to the end of the Middle Cambrian at which time one genus (*Dolichometopus*) appears briefly at Baltic sites.

A study of the morphologic features of the exoskeleton has led many Cambrian paleontologists to believe that one of the largest and most significant Cambrian trilobite stocks—the ptychoparoids—was derived from the primitive Ptychopariidae of the late Lower Cambrian (Rasetti, 1952, 1955). The stock maintains during the Middle Cambrian a generalized morphologic structure, extreme plasticity and intergradation between generic types. During the late Lower Cambrian the primitive Antagminae gave rise to the somewhat larger and more advanced types grouped in the Alokistocaridae. It becomes the dominant Middle Cambrian family in the intermediate and cratonic realms, reaching its peak in numbers and diversity in *Bathyuriscus-Elrathina* time. Its poor representation in the Cordilleran region in latest Middle Cambrian is

in part due to the undescribed condition of these assemblages, and in part due to the change in environment to which the family responded by giving rise to a number of new, better adapted groups—the Asaphiscidae, Marjumidae, Kingstonidae, Menomonidae, and Bolaspididae.

The Solenopleuridae and Anomocaridae also appear to belong to the ptychoparoid stock, but were derived from the Ptychopariinae branch and like their ancestors show a strong preference for the extracratonic euxinic biofacies. *Solenopleurella* is too ubiquitous to be significant. *Glyphaspis*, sole representative of the Anomocaridae, is either a specially adapted cratonic genus or is wrongly placed in this family.

The Oryctocephalidae, Ogygopsidae and Pagetidae are all small families and are restricted to miogeosynclinal sites—on figure 1 they occur only in the Langston and Spence assemblages. They show a strong preference toward the extracratonic euxinic biofacies. A biofacies control of their appearance in miogeosynclinal sites is indicated by the early appearance of all three families, their synchronous disappearance during the *Glossopleura* faunizone and reappearance in *Bathyuriscus-Elrathina* time. At this same time also one genus each of true extracratonic euxinic families, Burlingiidae and Corynexochidae, appear in the western miogeosynclinal sites. The Agnostidae also are now essentially adapted to the extracratonic biofacies. Only the ubiquitous *Peronopsis* is common in cratonic sites, but more genera appear in the intermediate realm.

The Dorypygidae continue to show an independent pattern. *Kootenia* and *Olenoides* appear in the Cordilleran region as leisurely immigrants from the northeastern boundary biofacies and move eastward onto the craton as the maximum inundation occurs. *Dorypyge* appears very briefly in the western miogeosynclinal sites but was apparently intolerant of cratonic biofacies conditions. *Holteria*, if correctly placed, must be a late indigenous genus.

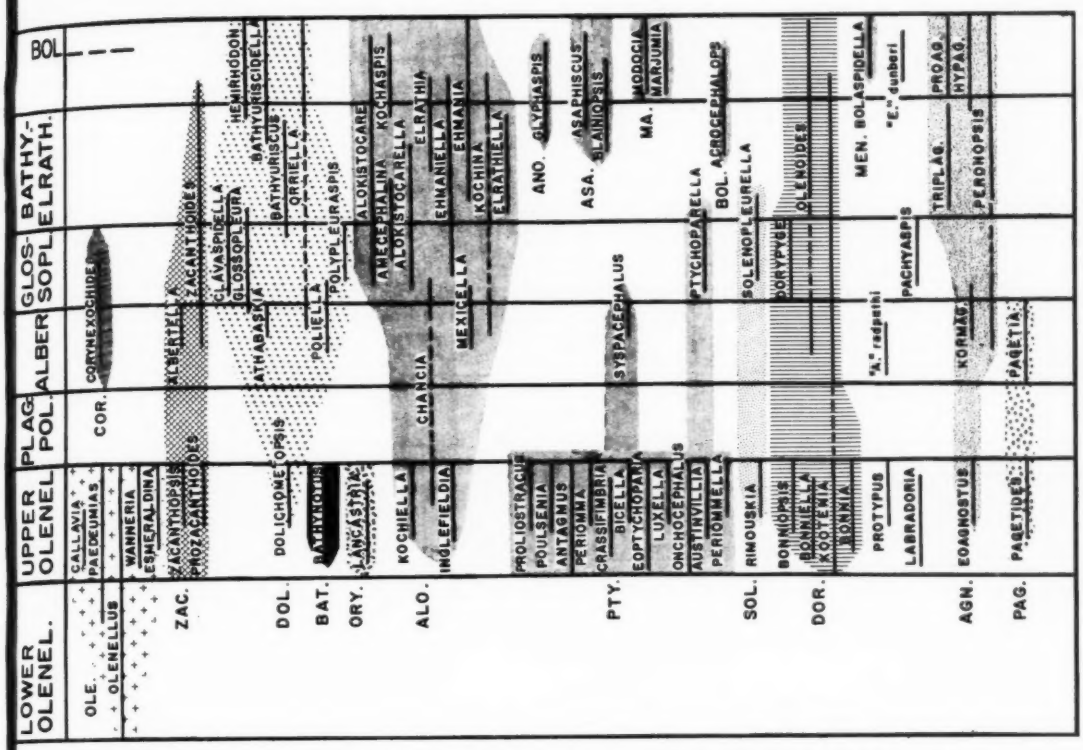
On both charts the familial patterns divide the epoch into an early half, embracing the *Plagiura-Poliella*, *Albertella* and most of the *Glossopleura* faunizones, and a later half dominated by the *Bathyuriscus-Elrathina* faunizone. The early half coincides with the continued transgression of the sea into the cratonic realm. Apparently the advancing seas carried with them some features of the extracratonic biofacies as it was during this time that the extracratonic faunal elements penetrated farthest eastward. The later half of the epoch was characterized by the wide extent of clear shallow seas and a carbonate lithofacies spreading from the miogeosyncline up onto the shelf areas. It was accompanied by the complete disappearance of any extracratonic faunal elements from the shelf areas, now farthest removed from the eugeosynclinal realm.

In the Middle Cambrian also a characteristic eugeosynclinal lithofacies and biofacies is not positively identified in the Cordilleran region, but in British Columbia (Rasetti, 1951) dark siliceous shales increase in the western sections. The miogeosynclinal sites are characterized by thick sections of dominantly carbonate rocks with some interbedded calcareous shales, overlying the initial transgressive sands and shales. These sequences thin and grade eastward into the cratonic sections with the percentage of calcareous shales increasing progressively at the expense of the pure carbonates.

Figure 3 shows assemblages from the cratonic realm and possibly some from the intermediate realm of eastern North America. Here sedimentation did not generally start much before the time of the *Glossopleura* faunizone. Recently Shaw (1954) listed a late *Albertella* faunizone assemblage from the Parker shale of Vermont, adding seven Cordilleran genera not previously known from eastern United States.

Albertella was added to the Zacanthoididae which are otherwise represented only by the long ranging *Zacanthoides*. *Syspacephalus*, sole genus of the Antagminae, was added to the Ptychopariidae. The Ptychopariinae are represented only by *Ptychoparella* in Greenland. The pattern for the Dolichometopidae is the same—a peak in the *Glossopleura* faunizone, *Bathyuriscus* as sole genus during *Bathyuriscus-Elrathina* time, and several new genera appearing in the latest Middle Cambrian.

The Alokistocaridae are again the dominant family, with several genera occurring exclusively in Greenland. The family reaches a peak in the *Bathyuriscus-Elrathina* faunizone, but shows only a moderate reduction in numbers in latest Middle Cambrian. This



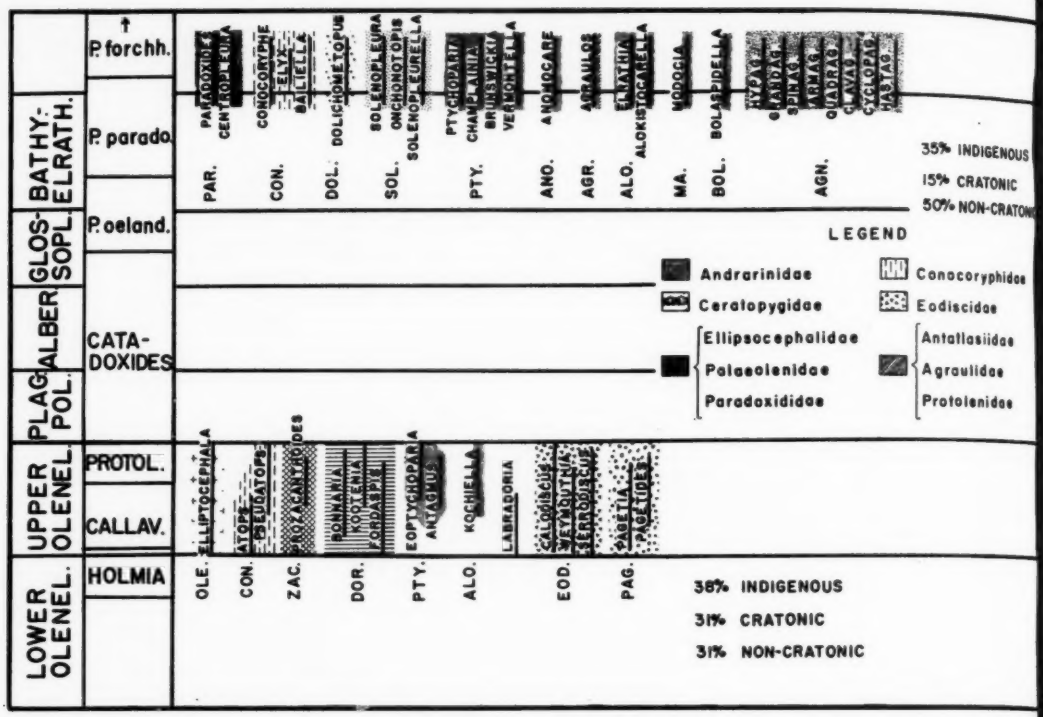
TEXT-FIG. 3—Lower and Middle Cambrian eastern North America—Cratonic and Intermediate Realms: Middle Cambrian—20% Non-cratonic; Lower Cambrian—8% Non-cratonic.

picture is the more accurate as it reflects our better knowledge of these faunas in the Appalachian region (Resser, 1938b, 1942a; Rasetti, 1948). The Asaphiscidae, Marjumidae, Menomonidae, and Bolaspididae also appear in latest Middle Cambrian, but only half the genera are the same as those in the Cordilleran region.

The Dorypygidae are represented by both *Olenoides* and *Kootenia* occurring sporadically from the beginning of sedimentation to the end of the epoch. *Dorypyge* is an exclusively arctic genus appearing in a *Glossopleura* assemblage from northern Greenland. Apparently the genus continued to live in north Atlantic waters as very late in Middle Cambrian it briefly invaded the Baltic province to the southeast. Like certain other northern Greenland genera its distribution suggests a preference for the outer edge of the intermediate biofacies. Nowhere does it occur in a normal cratonic assemblage.

Most of the Cordilleran families with significant extracratonic affinities do not appear on figure 3. The miogeosynclinal sites are poorly represented in the known Appalachian sequences. There are recorded only the Solenopleuridae (the ubiquitous *Solenopleurella*), the Anomocaridae (*Glyphaspis*), and Corynexochidae (an indigenous genus, *Corynexochides*). *Pagetia* makes a very brief appearance, apparently at the end of its teilzone in the east. The Agnostidae are better represented than in the Cordilleran miogeosynclinal sites, a phenomenon which may reflect their probable origin somewhere along the eastern side of the continent. Four genera, three also present in the Cordilleran region, are in common with the extracratonic euxinic biofacies assemblages of the Atlantic province.

Only one Middle Cambrian assemblage of mixed composition, the *Centropleura* fauna of Vermont, has been found in the east, figure 4. Although valuable in effecting a corre-



TEXT-FIG. 4—Lower and Middle Cambrian eastern North America—biofacies at outer margin of Intermediate Realm

lation between the cratonic and the extracratonic euxinic biofacies realms, the fauna's use is limited because the enclosing beds cover only a short time span in the latest Middle Cambrian. The familial pattern shows even stronger extracratonic affinities than in the *Elliptocephala* assemblage. The Paradoxididae, Conocoryphidae and Agraulidae are characteristically extracratonic euxinic families; the Anomocaridae, Solenopleuridae (except for *Solenopleurella*), Ptychopariidae and Dolichometopidae are represented only by extracratonic genera. The Agnostidae are well represented either by indigenous genera or forms from the extracratonic euxinic realm. The only cratonic affinities lie in the presence of *Elrathia* and *Bolaspidella*. Both genera are represented by enough specimens to indicate that they were not strays from the adjoining cratonic biofacies.

Figure 5 shows assemblages of the extracratonic euxinic realm. In the Acado-Baltic region sedimentation did not begin until the middle Middle Cambrian. The *Paradoxides oelandicus* zone most nearly equates with the late *Glossopleura* and early *Bathyuriscus-Elrathina* faunizones. Early Middle Cambrian faunas of Europe appear to be limited to the Mediterranean regions. The Paradoxididae, Conocoryphidae and Agraulidae are distinctive extracratonic euxinic families. The Paradoxididae, though *Paradoxides* is so abundant, is actually a much smaller family than the blind Conocoryphidae. The Solenopleuridae, Anomocaridae and Ptychopariidae are second in importance, represented by genera whose only affinities are in the *Centropleura* assemblage. *Burlingia* and *Schmalenseeia* belong to the Burlingiidae. The late and brief appearances of the Corynexochidae, *Dorypyge* and *Dolichometopus* are best interpreted as brief southward invasions from their home biofacies, the intermediate realm, in the north Atlantic. *Kootenia* appears briefly in these as-

semblages at a time which coincides with its maximum expansion throughout the Pacific province.

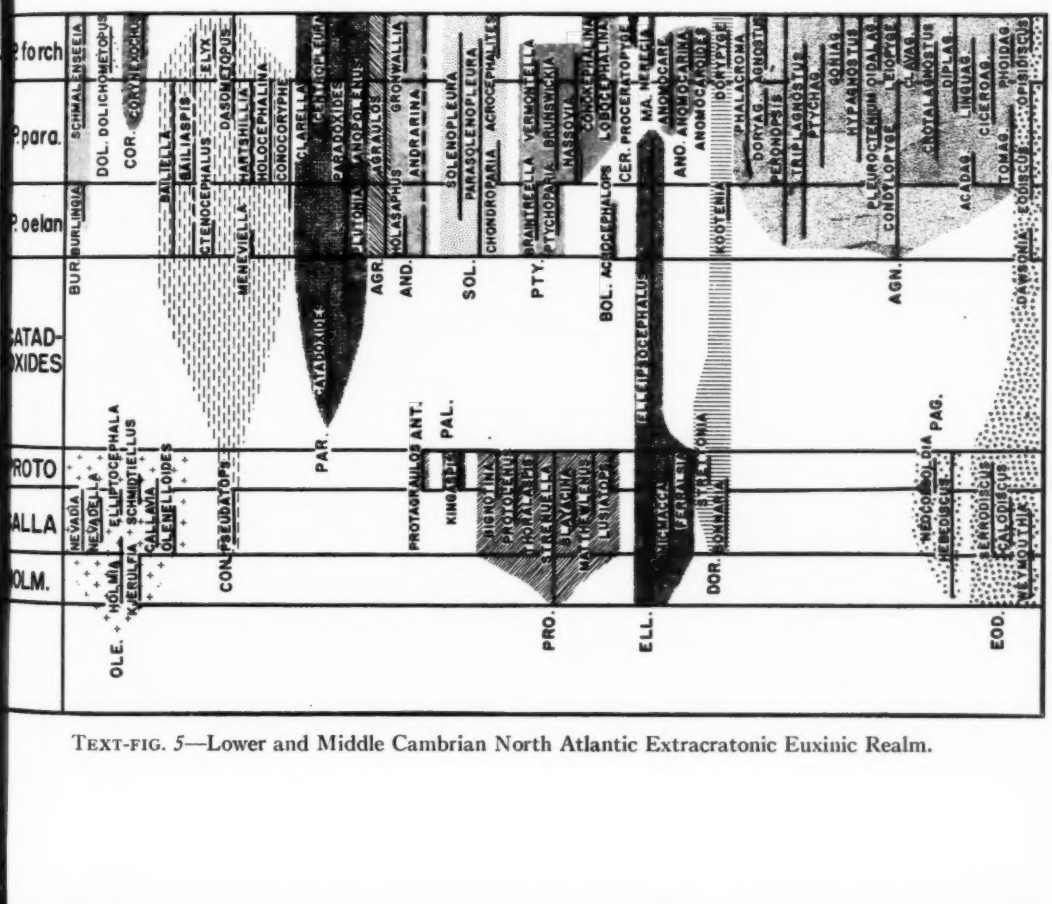
The Ceratopygidae, Andrarinidae and Conokephalininae are considered local derivatives of the ptychoparoid stock, but their ancestors are not definitely known. The early appearance of *Acrocephalops* suggests that it is not correctly placed in the Bolaspididae. *Elleipsocephalus* is a remnant of the late Lower Cambrian family.

The great abundance of the Agnostidae partly reflects the detailed work of Westergard on this group, but many of the genera occur also in the Cordilleran and northeastern North American sites and as far south as Australia. The increasing abundance of the Agnostidae towards and into the extracratonic euxinic realm, and the extremely wide geographic distribution of certain of the genera suggests a planktonic pelagic habitat for this group of trilobites. The Eodiscidae appear as a persistent but now insignificant group.

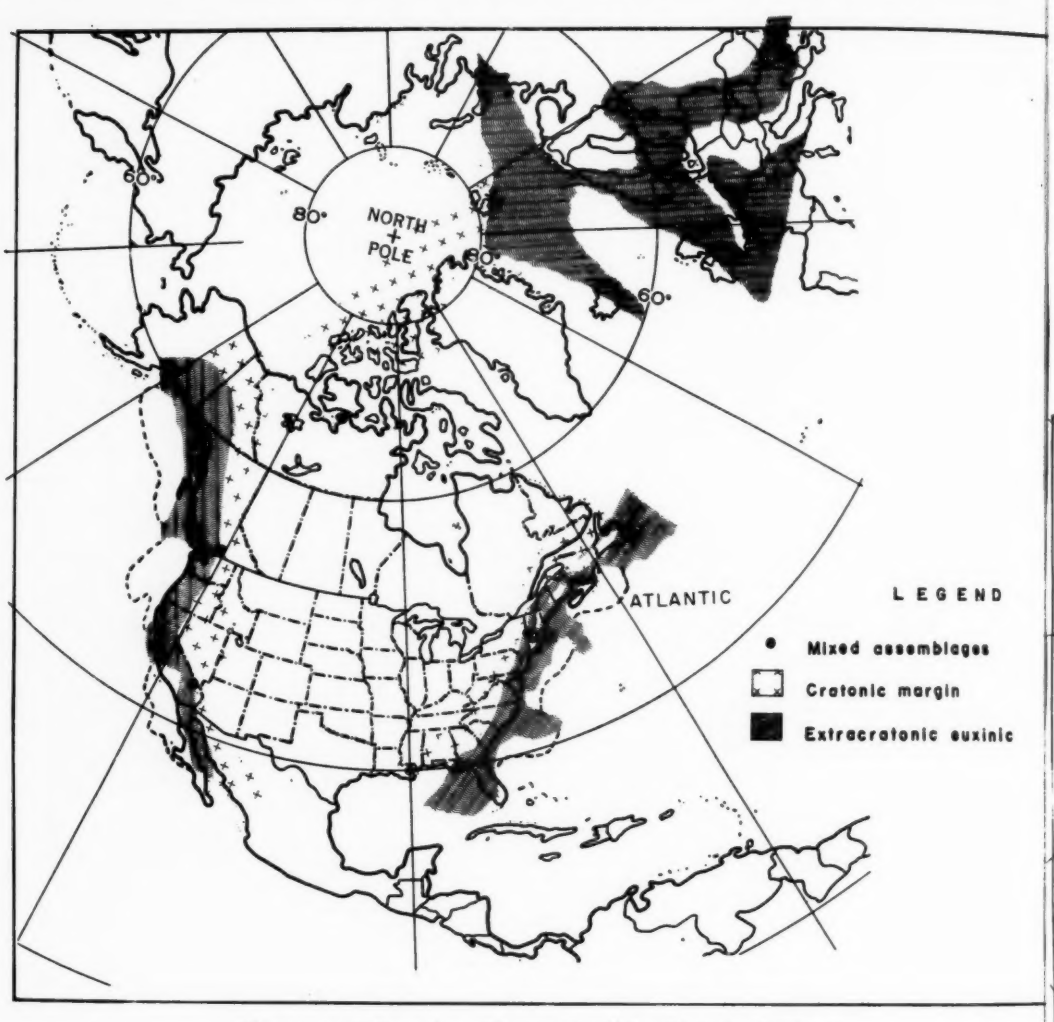
In the Acado-Baltic province the extracratonic euxinic biofacies occurs in a dominantly clastic lithofacies—dark gray-green sandstone, conglomerates, gray green argillaceous and arenaceous shales and subordinate lenses and nodules of dark argillaceous and arenaceous limestone. Pyrite, phosphate nodules and glauconite are common accessories. Near Oslo and in southeast Scania the gray Andrarum limestone up to 75 feet thick is the only good carbonate unit in the entire province. These beds carry three-fourths of the genera which show cratonic or boundary biofacies affinities. It would appear that for this brief time the environment changed sufficiently to permit an invasion by some of the more tolerant genera.

UPPER CAMBRIAN BIOSTRATIGRAPHY

Evolution of Ptychoparoid Stock.—During the latest Middle Cambrian and the Dresbachian stage there occurs a reorganization of trilobite familial patterns in all biofacies realms. The families which had appeared in



TEXT-FIG. 5—Lower and Middle Cambrian North Atlantic Extracratonic Euxinic Realm.

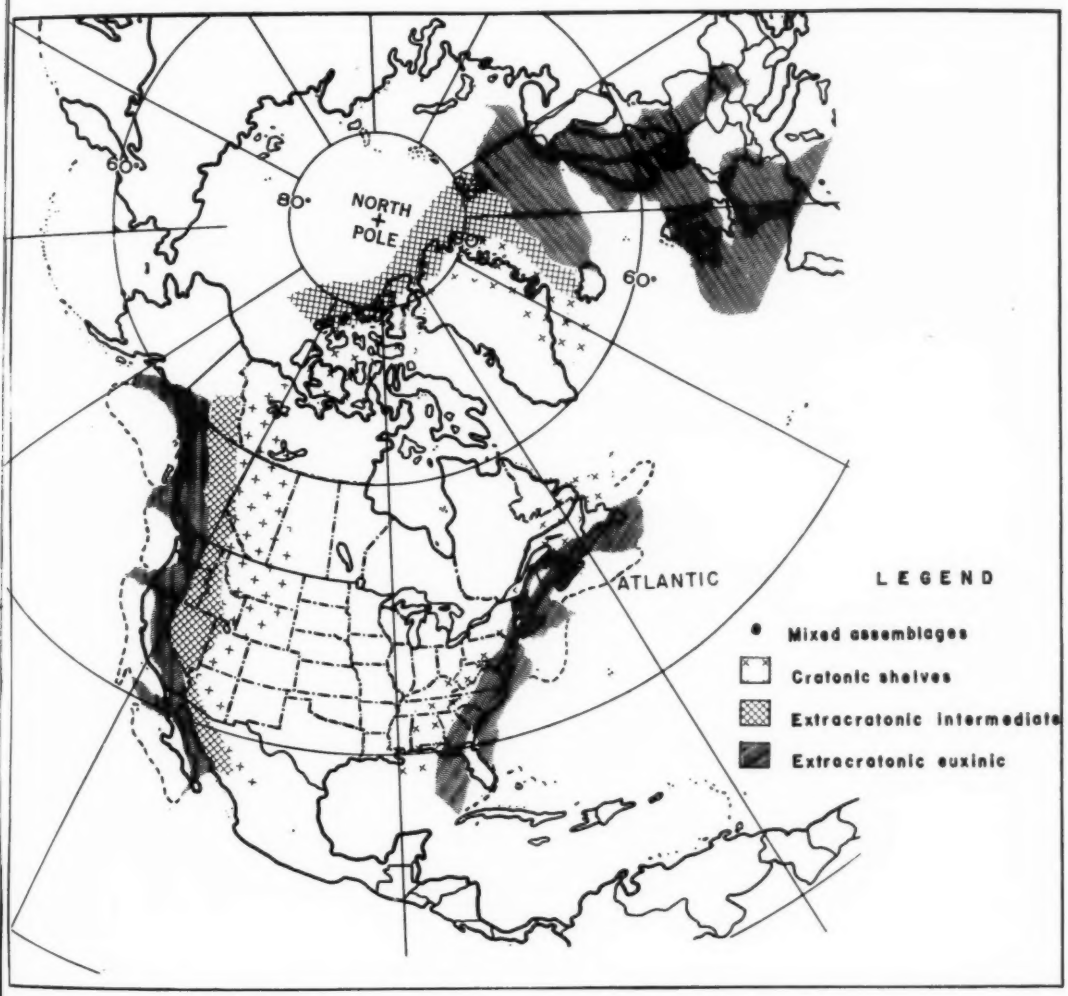


TEXT-FIG. 6—Location of Lower Cambrian Biofacies Realms.

late Lower Cambrian and furnished the characteristic Middle Cambrian assemblages die out rapidly. The fundamental cause of this faunal change was widespread tectonic movements affecting at least all the northern hemisphere. The changing tectonic pattern was first felt upon the shelf areas and adjoining miogeosynclinal borders by a cessation of downwarping and the gradual but steady outward encroachment of the continental shore line. Northern Laurentia was first affected by positive tectonic movements (no late Middle Cambrian or Dresbachian has been reported from the arctic sections). But in southern Laurentia oscillation occurred. The late Middle Cambrian shoaling was followed by a final negative pulse—a very moderate subsidence which, nevertheless, carried the seas into the interior United States across a broad reliefless coastal plain. The cratonic biofacies realm was expanded from Montana and Wyoming, across the northern states and through the Mississippi valley. But at the end of the Dresbachian the positive tectonism of Laurentia became dominant throughout the western hemisphere—the shelf areas became dry land; the miogeosynclinal areas

were partially exposed and with the influx of clastics took on more characteristics of the cratonic biofacies. The climax of this movement was reached at the level of the boundary between the Dresbachian and Franconian stages in the North American sequence, and at the level of the Middle-Upper Cambrian boundary in the Acado-Baltic sections.

In the intermediate and cratonic realms bordering Laurentia these physical changes in environment beginning in the late Middle Cambrian are reflected first by the disappearance of the Ptychopariidae, Ogygopsidae, Oryctocephalidae, Pagetidae, and Zacanthoididae and finally of the Dorypygidae, Dolichometopidae, Corynexochidae and Alokistocaridae. Only the ptychoparoid stock seems to have been able to adjust to the changing ecologic conditions. In the latest Middle Cambrian the Asaphiscidae, Kingstonidae, Bolaspididae, Menomonidae and Marjumidae appear, derived from genera of the Alokistocaridae. As the ancestral family dies out, a group of genera replaced them (the Marjumidae) which retained the

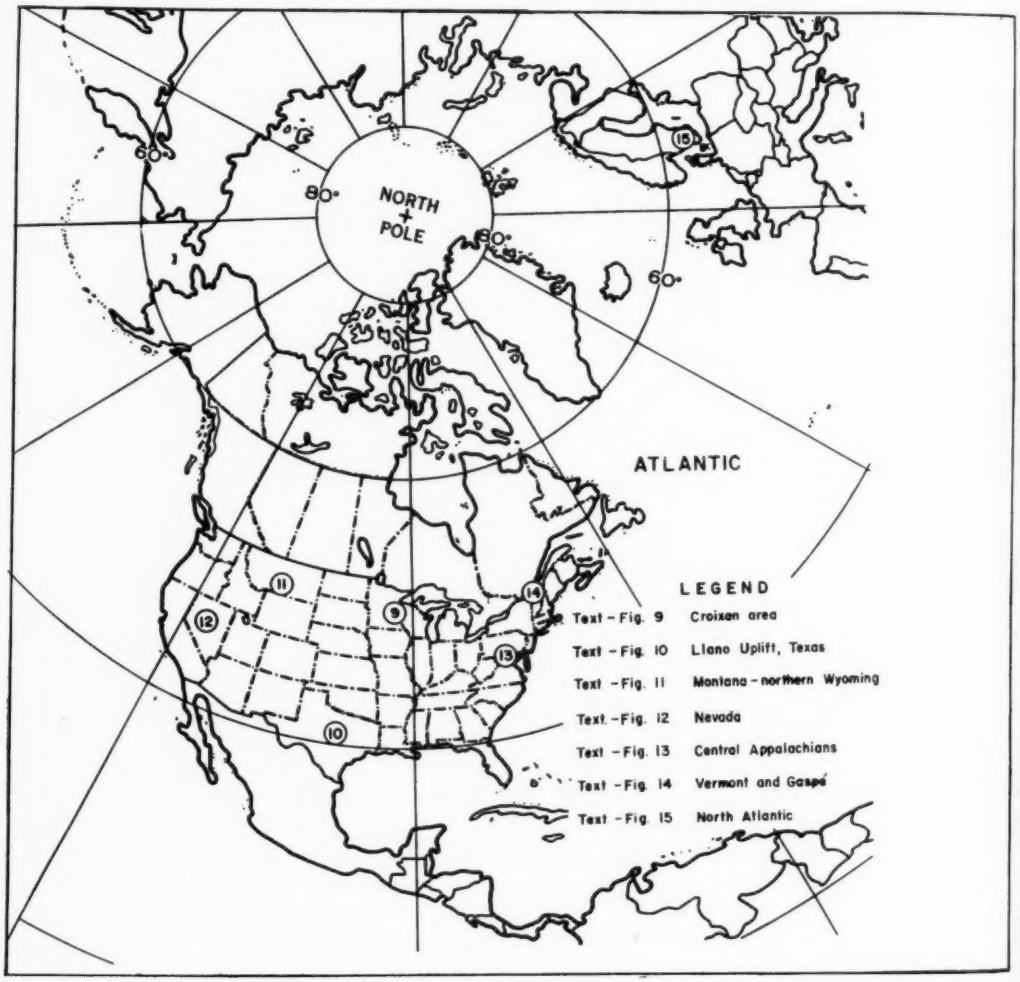


TEXT-FIG. 7—Location of Middle Cambrian Biofacies Realms.

essentially generalized morphology of the ptychoparoid exoskeleton with a few more advanced features—such as a narrower fixed cheek and larger pygidium. This group was the reservoir stock of many of the North American Upper Cambrian and Ordovician trilobite families.

The *Bolaspidella* subzone at the top of the highest Middle Cambrian faunizone carries an ideal transition assemblage composed of the last genera of the Middle Cambrian families mingled with the first genera of the rising new families. With the sudden expansion of the cratonic biofacies at the beginning of the Dresbachian, the new ptychoparoid stock experienced an evolutionary burst as many new groups developed to occupy the vacant habitats. On the charts, figs. 9–11, several different patterns are used to show relationships among the families. The Blountinae are believed derived from the Asaphiscidae, the Crepicephalidae, and Tricrepicephalidae derived from a genus like *Modocia*. The Llanoaspidae and Cedaridae may have developed from one basic form, but the other families are believed developed from independent ptychoparoid genera.

Careful correlation of stratigraphic position with evolutionary trends (Lochman,


NORTH POLE
80°
60°
ATLANTIC
LEGEND
Text – Fig. 9 Croixan area
Text – Fig. 10 Llano Uplift, Texas
Text – Fig. 11 Montana – northern Wyoming
Text – Fig. 12 Nevada
Text – Fig. 13 Central Appalachians
Text – Fig. 14 Vermont and Gaspé
Text – Fig. 15 North Atlantic

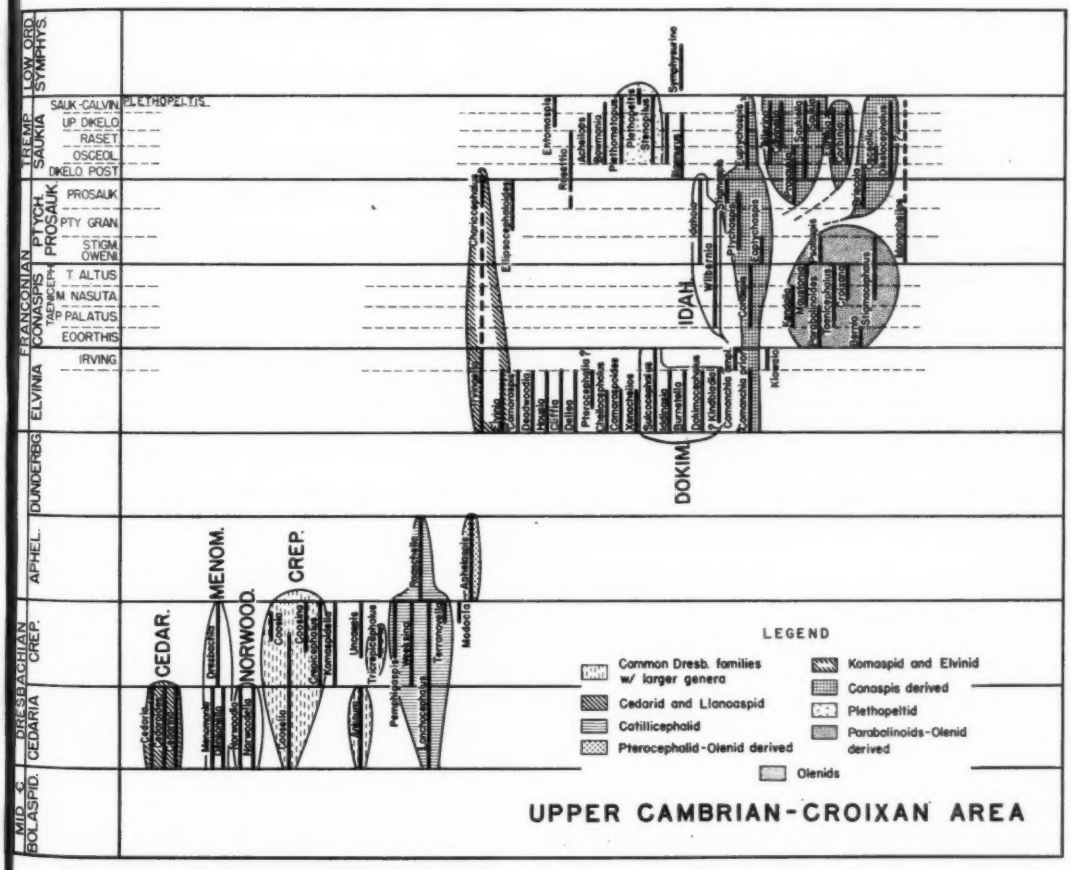
TEXT-FIG. *8*—Distribution of charted Upper Cambrian trilobite assemblages.

1956a; Palmer, 1954a; Rasetti, 1954b; Shaw, 1952) has now demonstrated that not only in the Dresbachian but also in the Franconian and Trempealeauan stages the ptychoparoid stock experienced recurring evolutionary bursts in response to critical biofacies changes in the cratonic realm. The Dokimocephalidae and Idahoiidae so developed in the early Franconian. In the late Franconian *Conaspis* gave rise to the Ptychaspididae, Eurekiidae and Saukiidae, while the Dikelocephalidae are believed derived from several genera of the Idahoiidae (Lochman, 1956a) (see footnote 2).

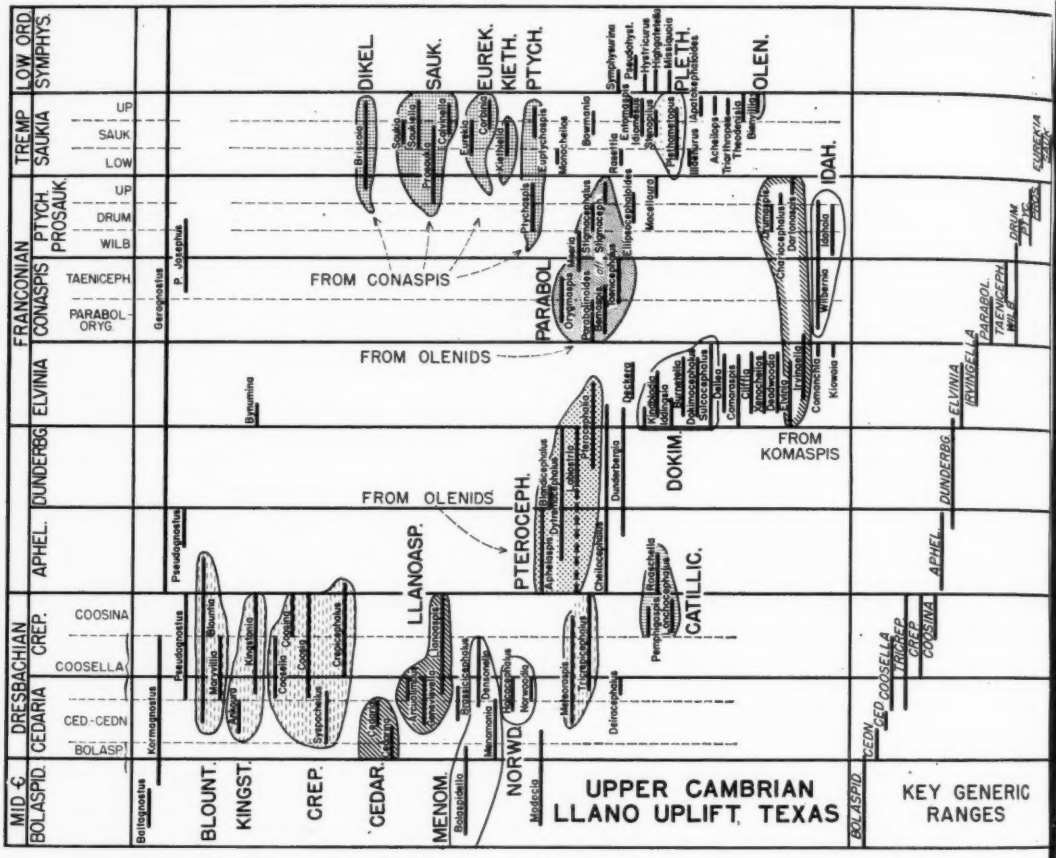
One long ranging family,[1] the Komaspidae, occur sporadically in the cratonic realm. This group was derived from the Ptychopariidae soon after the middle Middle Cambrian in eastern Asia with the appearance of *Komaspis*, which with *Irvingella* and *Irvingelloides*, forms a nearly unchanged basic stock through the Upper Cambrian and Lower Ordovician (Lochman, 1953). The similarity of this family's pattern to that of the Dorypygidae leads us to believe that it too was indigenous to a boundary biofacies at the outer edge of the intermediate realm in the arctic regions. When ecologic conditions were favorable, genera of the family would appear briefly in the cratonic realm.

In the extracratonic euxinic realm there were no apparent ecologic changes until near the end of the *P. forchhammeri* fauni-

[1] The genera *Bynumina* and *Bynumiella*, presently placed in the Kingstonidae, are not believed genetically related to the Dresbachian genera of the family.



TEXT-FIG. 9.—Upper Cambrian Cratonic Realm in Croixan area. (From published work by Bell, Berg, Feniak, Kurtz, Lochman, Nelson and from unpublished faunal lists by Raasch.)



TEXT-FIG. *10*—Upper Cambrian Cratonic Realm, Llano Uplift, Texas. (From published work by Palmer and Wilson and unpublished descriptive paleontology by Ellinwood, Wollman, Winston.)

zone. We notice only a gradual reduction in genera of the characteristic families. A forecast of changes to come appears with the extinction of the Ptychopariinae in the lower *P. forchhammeri* zone followed by the sudden though brief appearance of a number of intermediate biofacies genera in the Andrarum limestone and the extinction of the Conocoryphidae. Then after a short respite the effects of the positive tectonism are finally felt in the extracratonic euxinic realm and the rest of the dominant Middle Cambrian genera die out—Paradoxididae, Agraulidae, Andrarinidae and Anomocaridae. One or two genera, clearly the die-hards, appear briefly in the overlying basal Upper Cambrian beds, before the final extinction of their families—the Burlingiidae (*Schmalenseeia*), the Conokephalininae (*Conokephalina*), and the Solenopleuridae (*Acrocephalites*, *Cliffia*, *Apachia*). Although the Agnostidae reached their climax in this realm during the Middle Cambrian, they continued into and through the Upper Cambrian and into the Lower Ordovician in ever dwindling numbers.

In this realm also it was primarily the ptychoparoid stock which responded to the changes by giving rise to better adjusted genera. The Ptychopariinae, Andrarinidae and Conokephalininae were the parent families from which arose *Nerecia*, a very generalized form like the primitive Marjumiidae; the related genera *Maladioidella* and *Aphelaspis*, ancestors of the Pterocephalidae; the Ceratopygidae; the Olenidae; and

a number of primitive olenid-like genera—*Eugonocare*, *Olenaspella*, most of them remaining out in the extracratonic realms. However, *Aphelaspis* followed the changing biofacies southward and dominated the assemblages around Laurentia during the transitional stage. Somewhat later the Ceratopygidae stock gave rise to the inconspicuous Housiidae and the Parabolinoididae arose from *Olenaspella* or a similar olenid genus. The Olenidae, a long-lived, slowly evolving, well-adapted family, characterizes the extracratonic euxinic realm through the Upper Cambrian and Lower Ordovician. But the Pterocephalidae and the Parabolinoididae, though their ancestors came from this realm, experienced the same evolutionary trends of sudden expansion, then gradual decay and extinction, upon the craton as did the ptychoparoid stocks of cratonic origin.

Certain of the trilobite families now appear to be true phylogenetic groupings, rather than merely scattered morphologic groups, when the generic ranges are checked against the stratigraphy. With respect to their geographic position, the families also show a direct relationship to a particular biofacies realm. In the Middle Cambrian the Paradoxididae, Agraulidae, Conocoryphidae and Ptychopariinae were unique to the extracratonic euxinic realm, and were followed in the Upper Cambrian by the Olenidae showing a similar restriction.

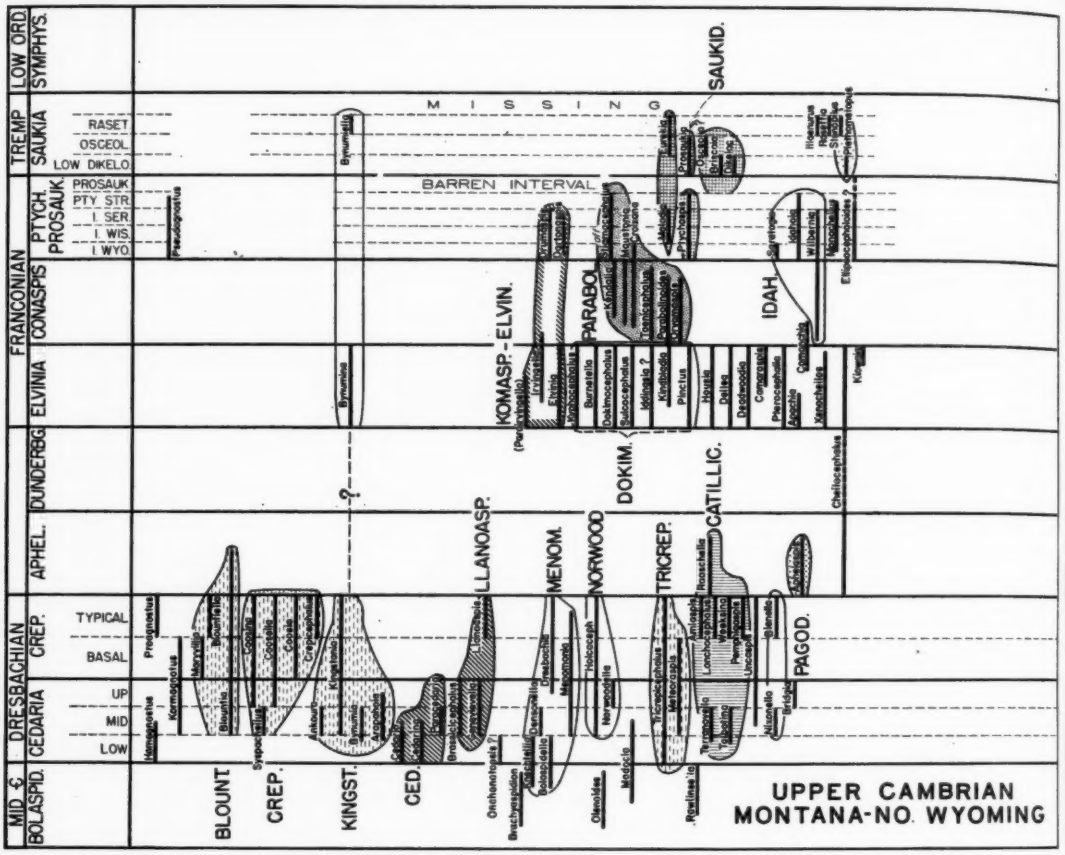
In the Upper Cambrian the two families, Pterocephalidae and Parabolinoididae, appear to have originated from primitive olenid genera which were able to migrate from the extracratonic realms into the cratonic sites where the evolutionary development of the families occurred. Their members were the dominant and widespread genera of the craton biofacies at their respective times. No similar phenomenon has been observed in the Middle Cambrian. It is believed that the relatively sudden and drastic ecologic changes which occurred several times during the Upper Cambrian across the biofacies realms bordering Laurentia were responsible for this phenomenon.

Certain families apparently originated within the intermediate biofacies. These families are most valuable for correlation since their genera frequently show a wide tolerance to ecologic conditions in the adjoining realms and from time to time appear associated with these assemblages. These families are not numerous—the Dorypygidae and Dolichometopidae of the Middle Cambrian, the Catillicephalidae of the Upper Cambrian, the Kainellidae of the Lower Ordovician, and the Komaspididae-Middle Cambrian through Lower Ordovician.

Finally there are the families which are typical of the craton, originated within or close to the cratonic sites, and evolved within the cratonic biofacies. These are predominately the ptychoparoid stock—the Alokistocaridae of the Middle Cambrian, their descendants in the Dresbachian (the Kingstonidae, Bolaspididae, Asaphiscidae, Menomonidae, Crepicephalidae); in the Franconian *Conaspis*, and the derived Saukiidae, Ptychaspididae and Eurekiidae; the Idahoiidae (from some ancestral genus of the intermediate realm) and the derived Dikelocephalidae.

Faunizones of the Cratonic Biofacies.—The Upper Cambrian charts (figs. 9–15) include at the bottom the *Bolaspidella* subzone (*Deissella-Centropleura* of 1944 Cambrian Correlation Chart) which is recognized at the top of the Middle Cambrian. In Montana and Texas 40–45% of the characteristic genera of this subzone range into the lower part of the *Cedaria* faunizone (fig. 11) although it must be admitted that the assemblage of this subzone is as yet incompletely described. This overlap of genera is known only at sites located on the outer edges of the Dresbachian shelf areas.

The faunas of the *Cedaria-Crepicephalus* faunizones are often regarded as the typical Dresbachian assemblages. These faunal units were first designated from the Croixan area (fig. 9) where discontinuous deposition and hiati are conspicuous in the section. From their teilzones in this area the genera appeared segregated into an early assemblage characterized by genera of the Cedariidae and a later assemblage in which individuals of *Crepicephalus* were numerous, with only two genera occurring in both assemblages. Later work in Montana (fig. 11) and Texas (fig. 10) demonstrated that in other parts of the cratonic realm many of the genera exhibited longer teilzones. As more assemblages were described and a



TEXT-FIG. *11*—Upper Cambrian Cratonic Realm, Montana-northern Wyoming. (From published work by Lochman and Duncan and by Shaw and Deland, and from unpublished descriptive paleontology by Grant.)

more complete cratonic biozone of each genus was obtained, intracratonic correlation was effected by use of the faunizone concept. The presence and position of the *Cedaria* faunizone is recognized by the median level of overlap of the biozones of *Cedaria, Cedarina, Bynumia, Genevievella, Syspacheilus, Araphoia* and *Ankoura;* and of the *Crepicephalus* faunizone by the median level of overlap of the biozones of *Tricrepicephalus, Crepicephalus, Lonchocephalus, Llanoaspis, Coosia* and *Coosina.* The described *Cedaria-Crepicephalus* faunas now comprise 12 families and over 43 genera, many having biozones spanning a greater or less portion of both faunizones. The familial pattern clearly shows the biologic unity of the assemblages of these two faunizones. The family stocks migrated into the enlarged shelf areas at the beginning of *Cedaria* time and evolved in situ in the favorable biofacies.

The most important and pronounced faunal change of the entire Upper Cambrian biostratigraphic sequence occurs at the boundary level between the *Crepicephalus* and the *Aphelaspis* faunizones (Howell and Lochman, 1939; Lochman, 1956a; Palmer, 1954a; Wilson, 1957). Only *Blountia* is known certainly to range across it. Palmer (1954a) describes a species, *Crepicephalus? perplexus,* from the base of the *Aphelaspis* faunizone in Texas which may represent a late and aberrant member of the Crepicephalidae just barely crossing this major faunal change. The break is equally sharp at

the familial level. The Blountinae (*Blountia*) and the Catillicephalidae (*Raaschella*) are the only families to cross this boundary, and both of them are extinct before the end of the *Aphelaspis* faunizone. As previously mentioned, *Bynumina* and *Bynumiella* are not considered genetically related to the Dresbachian Kingstonidae.

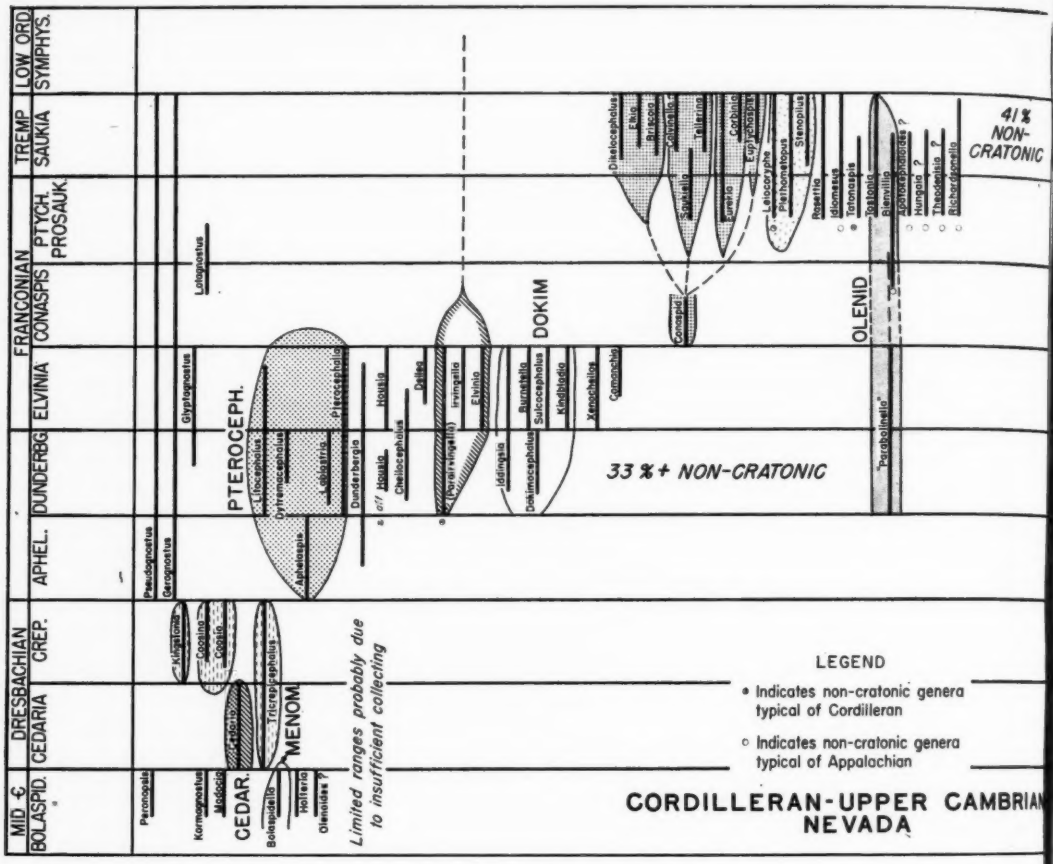
At nearly all the cratonic sites the upper boundary of the *Aphelaspis* faunizone shows as pronounced a faunal break as the lower and is accompanied by a conspicuous physical break or change in sedimentation (figs. 9, 11). But in the sections on the southeast side of the Llano Uplift in Texas neither a physical nor a faunal hiatus exists (fig. 10) and some of the genera of the *Aphelaspis* faunizone associated with additional new pterocephalid genera occupy a series of passage beds below the base of the *Elvinia* zone. From these beds *Cheilocephalus, Pterocephalia* and *Dunderbergia* continue up into the *Elvinia* faunizone.

Most of these passage beds were referred to as post-*Aphelaspis* zone by Palmer (1954a), but the lower portion was included in the top of his *Aphelaspis* faunizone. Figure 10 shows that the characteristic faunal assemblage of these beds consists of the pterocephalid genera—*Blandicephalus, Labiostria* and *Dytremacephalus granulosa*—*Cheilocephalus* and *Dunderbergia*. In Texas the teilzone of the latter genus starts only a short distance below and ends only a short distance above the span of these passage beds. *Dunderbergia* is also common in the Cordilleran intermediate biofacies of Nevada (fig. 12) where it has a somewhat longer range. From these occurrences the probable biozone of *Dunderbergia* may be derived. The passage beds between the *Aphelaspis* and the *Elvinia* faunizones in both Texas and Nevada occupy a position spanning the median level of the *Dunderbergia* biozone. It is proposed that this biostratigraphic unit be known as the *Dunderbergia* faunizone. Most of the faunas at this position in the fully developed sections of the Cordilleran miogeosynclinal sites have not been described; consequently the characterization of the diagnostic genera and their biozone limits is at present tentative.

The recognition of the *Dunderbergia* faunizone necessitates a clarification of the typical *Aphelaspis* assemblage. As here used the *Aphelaspis* faunizone is characterized by the first appearance and maximum abundance of *Aphelaspis* in association with *Cheilocephalus* (also first appearance and maximum abundance), *Raaschella*, and the first appearance of *Dunderbergia* and *Labiostria* near the top of the unit. At all the shelf sites it corresponds exactly with the teilzone of *Aphelaspis* but in the miogeosynclinal assemblages the biozone of *Aphelaspis* appears to extend from the base of the *Aphelaspis* faunizone to the top of the *Dunderbergia* faunizone (fig. 12).

We propose the elimination of the *Aphelaspis* faunizone from the Dresbachian stage. Throughout the cratonic and intermediate realms wherever the *Crepicephalus* assemblages and the succeeding *Aphelaspis* assemblages can be recognized, this pronounced faunal break at the base of the *Aphelaspis* faunizone is equally sharp and distinct. In the Croixan area, type area of the Dresbachian, the Dresbach sections carry almost exclusively the *Cedaria-Crepicephalus* assemblages. *Aphelaspis* is known only in one small outcrop area in the St. Croix valley (Nelson, 1951), and from one core at Waconia, Minnesota. Normal marine sedimentation generally ceased in the Croixan area at or soon after the beginning of *Aphelaspis* zone time, and there is a break in the faunal succession until the base of the *Elvinia* faunizone. The *Aphelaspis* faunizone should be combined with the *Dunderbergia* faunizone to constitute a new stage between the Dresbachian and the Franconian. The name and type section for this new stage should be chosen from the Great Basin region where a nearly complete faunal succession for this part of the Upper Cambrian exists (Palmer in Nolan, et al., 1956; Drewes & Palmer, 1957; Palmer, 1956)

The *Elvinia* faunizone as developed in the cratonic biofacies is an "ideal zone" in that it is comprised of a vertically sharply bounded assemblage of widespread genera. The base of the unit coincides with the appearance of *Elvinia* and the beginnings of the Dokimocephalidae. Most of these genera are believed to have had a western origin in the intermediate biofacies. In Nevada some of the genera first appear in the *Dunderbergia* faunizone and the boundary between the



TEXT-FIG. *12*—Upper Cambrian Intermediate Realm in Nevada. (From published work of Palmer with revision by Palmer.)

two zones is gradational (fig. 12). Over the shelf the top of the *Elvinia* zone is marked by a thin, persistent subzone with *Comanchia* and a great abundance of *Irvingella* individuals (Wilson & Frederickson, 1950). Essentially the entire assemblage becomes extinct at the top of the faunizone. Only *Irvingella* and *Comanchia* continue into the base of the *Conaspis* zone. *Irvingella* is a member of the long-lived Komaspididae and "*Comanchia*" *prior* is a possible ancestor of the conaspid lineage. These are the only relationships which the trilobites of the *Elvinia* faunizone show to any of the later Upper Cambrian genera.

The boundaries of the *Aphelaspis* and *Elvinia* faunizones in the North American cratonic sites are defined by almost complete faunal changes. The changes are believed caused by the relatively rapid and mandatory responses made by the shelf biotas to pronounced environmental changes in the area. These environmental changes coincided with widespread emergence and shallowing of the seas over the North American cratonic and miogeosynclinal areas which reached a climax during *Dunderbergia* zone time. Consequently, upon the craton these two faunizones are easily and clearly defined by 1) naturally segregated generic assemblages, 2) individual key genera, and 3) the ranges of the major families.

The *Conaspis* faunizone is chiefly characterized by the appearance and development of the Parabolinoididae in association with *Wilbernia*. *Conaspis*, the name genus, is found only in the Croixan region (in great abundance) and in the Appalachians. It was

apparently restricted and inhibited by the prevailing ecologic conditions. Usually an abundance of *Taenicephalus* individuals marks the upper part of the zone. Throughout the cratonic sites the strata carrying the *Conaspis* assemblage are noticeably thinner than those of the adjoining faunizones. The abrupt extinction of the *Elvinia* assemblage and the appearance and flourishing of the Parabolinoididae, with obvious olenid affinities, leads us to believe that a change in ecologic conditions from those of *Elvinia* zone time must have occurred over the shelf areas for the relatively short time span of the *Conaspis* zone.

The overlying *Ptychaspis-Prosaukia* faunizone assemblages indicate a gradual stabilizing of cratonic conditions which led to the dwindling and extinction of the dominant Parabolinoididae. Under these new conditions *Conaspis* experienced an evolutionary burst, giving rise first to the Ptychaspididae, then the Saukiidae and finally the Eurekiidae.[2] Both the Idahoiidae and the returning Komaspididae also experienced evolutionary growth. The family lineages in this faunizone are among the best known in the Upper Cambrian because of the detailed stratigraphic work on this part of the section which has recently been completed in Montana, Texas and the Croixan region.

On the 1944 Cambrian Correlation Chart the uppermost Upper Cambrian is divided into five faunal units which are actually based on teilzones of the Croixan area. Subsequently Raasch (1952) proposed the *Saukia* faunizone to accommodate all the intracratonic assemblages at this position. Locally upon the craton from three to five zonules have been recognized within this faunal unit (figs. 9, 10, 11). These assemblages are characterized by the continued evolution of the Dikelocephalidae, Saukiidae, Eurekiidae and Ptychaspididae; the disappearance of *Ptychaspis* and the genera of the Komaspididae and Idahoiidae; and the appearance of a small group of smooth trilobites, the Plethopeltidae. Near the middle of the faunizone a number of small genera from the extracratonic *Hungaia* assemblage make their way into the shelf areas of the interior states (*Theodenisia, Bienvillia, Acheilops, Idiomesus, Stenochilina, Apatokephaloides*). The *Saukia* faunizone comprises the Trempealeauan stage as recommended by Bell, et al. (1956, p. 435).

The end of the Late Cambrian is marked by the extinction of the Dikelocephalidae and Saukiidae, families which had obviously become well adapted to the particular set of ecologic conditions prevailing upon the craton during the Trempealeauan. Much of the cratonic shelf became emergent at this time (throughout the northern and central interior states) and the deposits of the cratonic edges and adjoining miogeosynclinal sites show evidences of very shallow water conditions with sporadic exposure. Only a few genera survived the intensified competition in the restricted space.

Certain subzones, as parts of the major standard faunizones, have been mentioned specifically. These subzones are faunal units which are consistent in stratigraphic position over a wider area of the cratonic realm than the local teilzones and zonules. A *Coosina* or upper *Crepicephalus* subzone, limited by the close association of *Tricrepicephalus, Coosina, Pemphigaspis* and *Llanoaspis*, can be recognized on the interior craton in Wisconsin and Texas and eastward to the edge of the miogeosyncline in the central and southern Appalachian region. The *Irvingella* subzone (*Irvingella major* zone of Wilson and Frederickson, 1950) is characterized by an abundance of *Irvingella* with *Sulcocephalus candidus, Comanchia amplooculata* and *Kiowaia* and has been recognized over the entire shelf area. The *Taenicephalus* subzone (with an abundance of *Taenicephalus* and *Wilbernia*) is a good biostratigraphic unit in the upper part of the *Conaspis* faunizone for the Croixan area and the Midcontinent and Texas, but not elsewhere. The appearance of the extracratonic genera from the *Hungaia* assemblage upon the craton in the upper part of the *Saukia* faunizone can be used to delineate a high Trempealeauan subzone recognizable from Texas, through Missouri and into the Croixan area (figs. 10, 9).

Within the cratonic realm of the shelf areas, the delineation of practical biostratigraphic units can be established on the basis

[2] J. L. Wilson (1957) believes that the Dikelocephalidae also arose from the conaspid stock (figs. 9–13); but Lochman (1956a) postulates a polyphyletic origin for the family from several species of *Wilbernia*.

of the overlapping of biozones of certain abundant and widespread genera and also on the vertical ranges of certain families. Only the *Aphelaspis* and the *Elvinia* faunizones contain vertically segregated assemblages with abrupt sharp boundaries at both top and bottom.

Faunizones of the Extracratonic Biofacies.—The standard Upper Cambrian faunizones of the cratonic realm become less distinct as one moves out into and across the intermediate realm of the miogeosynclines and disappear completely in the dark argillaceous facies of the extracratonic euxinic realm. Late Cambrian faunal sequences of the intermediate realm are known from both the southwestern (Utah-Nevada) and the southeastern (Appalachians) sides of the Laurentian craton, and the sequences are somewhat different in the two areas. Actually the stratigraphic paleontology of the extracratonic sites has barely been started.

Bolaspidella now appears as a late Middle Cambrian genus of the intermediate realm which fortunately penetrated onto the edges of the shelf in Montana and Texas with the advancing Dresbachian subsidence, and thus managed to overlap the range of *Cedaria*. *Bolaspidella* is known from exotic boulders in the Marathon-Ouachita region and is common in the late Middle Cambrian carbonates and calcareous shales of Utah. In New England *Bolaspidella* appears both in the outer boundary facies of the *Centropleura* assemblage and in the Rockledge conglomerate and Hungerford shale in an assemblage of definite cratonic *Cedaria* zone affinities (Shaw, 1952). It is quite possible that *Bolaspidella* indicates the contemporaneity of deposition of the St. Albans shale on the outer edge of the miogeosyncline and the Rockledge sandy limestone and limestone conglomerates farther west on the miogeosyncline. Also common to both the Cordilleran and the Appalachian regions are the dorypygid genus *Olenoides*, and *Modocia* (syn. *Armonia* and *Metisia*) one of the earliest generalized ptychoparoids derived from the Alokistocaridae.

Across the Cordilleran intermediate realm at least as far as eastern Nevada *Cedaria* and *Crepicephalus* assemblages similar to those on the craton can be recognized as distinct. The part of the section occupied by the *Cedaria* faunizone thickens steadily westward (a tendency already noticeable in west central Montana) and is well over 1,000 feet in the House Range. But the *Crepicephalus* faunizone strata thicken only moderately westward.

In the southern Appalachians a large fauna from the Nolichucky shale has been described by Resser (1938b), but there is not sufficient stratigraphic data from the collecting localities to permit charting the genera. The faunal lists have been reexamined by G. O. Raasch who regards them as indicating that the *Cedaria* and *Crepicephalus* faunizones are distinct in this area. It is believed that the site of deposition of these strata was on the outer edge of the unstable shelf.

In the northern Appalachians *Cedaria* itself is known only from the Lévis boulders and the Murphy Creek formation of the Gaspé region (Kindle, 1948). Another cedarid, *Acrohybus*, occurs in the Rockledge conglomerate. The presence of *Arapahoia*, a Cordilleran key *Cedaria* zone genus, in the western Newfoundland section permits recognition of a distinct *Cedaria* faunizone in this region.

A large number of the early Upper Cambrian genera which range through both the assemblages in the cratonic realm have been described or listed from many localities in the northern and central Appalachians: Cape St. George, Newfoundland and Cowhead Peninsula (Lochman, 1938); Lévis boulders, western Gaspé (Rasetti, 1946); northwestern Vermont (Raymond, 1937; Shaw, 1952, *in press*); Pennsylvania and Virginia (Tasch, 1951; Wilson, 1952). Some of these genera are present at nearly all Appalachian localities whereas others are provincial. The ubiquitous genera belong to the Blountinae, Kingstonidae, Crepicephalidae, and Tricrepicephalidae, the same family groups which are most common upon the craton and in the Cordilleran miogeosyncline. In the central Appalachians where the stratigraphic sequence of the Dresbachian stage strata is best known, a *Cedaria* faunizone assemblage can not be separated as distinct from a *Crepicephalus* faunizone with the exception of the generic assemblage characteristic of the *Coosina* or upper *Crepicephalus* subzone, which may be distin-

guished. Both Tasch (1951) and Wilson (1952) had difficulty in delineating the faunizones within the Warrior formation of Pennsylvania. These faunas are about 25% non-cratonic in composition.

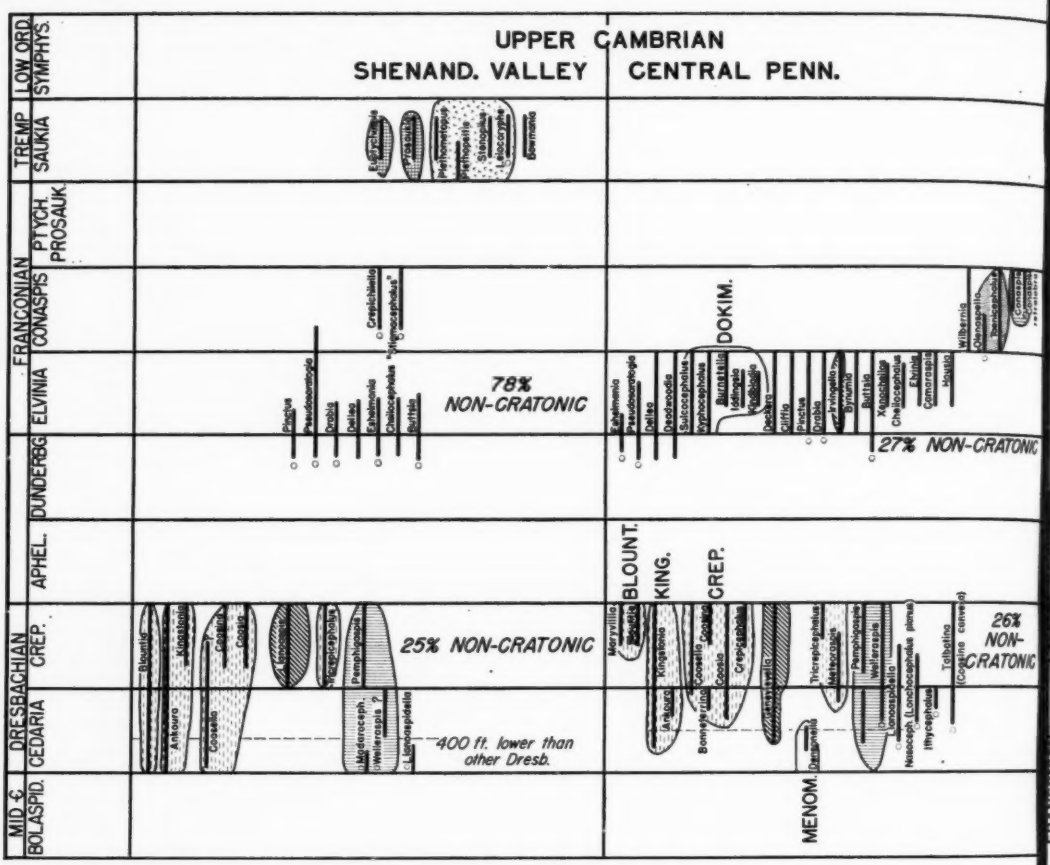
The Dresbachian assemblages known from northwestern Vermont and the Lévis boulders of the Gaspé (Rasetti, 1946) show the most difference from those of the craton. Rasetti's larger assemblage of 26 genera contains about 50% non-cratonic genera several of which occur elsewhere in the central and southern Appalachians. In these boulder conglomerates distinct assemblages cannot be distinguished, but Rasetti states that "an approximately equivalent fauna occurs in place in the Murphy Creek formation in eastern Gaspé." Kindle (1948) reports *Cedaria* and *Crepicephalus* occurring in the same bed at this locality. The Murphy Creek formation consists of thin-bedded, dark limestone and shale. The Cowhead Breccia and Cape St. George assemblages have a strong cratonic aspect except for the presence of the Catillicephalidae. These eastern Canadian faunas are all considered located within the intermediate realm of the miogeosyncline. They suggest that as one goes farther out into the intermediate biofacies the cratonic distinctions between the *Cedaria* and the *Crepicephalus* faunizone assemblages are gradually lost.

The Vermont assemblages contain 22 genera of which 10 or 45% are non-cratonic. Shaw (1952) believes this assemblage shows strongest affinities with the *Cedaria* faunizone. Though there is a break in sedimentation above the Hungerford shale, we think there is still an open question as to whether the apparent absence of a *Crepicephalus* zone assemblage in this region is 1) because of the lack of sedimentation, or rather 2) because ecologic conditions at this miogeosynclinal site produced a biofacies aspect allied to that of the *Cedaria* faunizone during all of Dresbachian time.

The same drastic extinction of the *Cedaria-Crepicephalus* assemblage occurs in the intermediate biofacies of both the Cordilleran and Appalachian areas; but the sequence immediately above this boundary is quite different for the two miogeosynclines. In Texas and in the Cordilleran miogeosyncline the succeeding strata can be divided into a lower unit—the *Aphelaspis* faunizone —which contains many individuals of a very small assemblage—*Blountia* and *Pseudagnostus*, continuing from below, and *Aphelaspis*, *Cheilocephalus* and *Raaschella*, appearing abruptly at the base of the unit. An upper unit—the *Dunderbergia* faunizone —is characterized by the presence of *Dunderbergia*, the evolutionary development of the Pterocephalidae and the disappearance of *Blountia* and *Raaschella*. This sequence is now known from the southeast side of the Llano uplift (Palmer, 1954a), the exotic boulders of the Marathon uplift (Wilson, 1954a), in the Great Basin (Palmer in Nolan, et al, 1956; Drewes & Palmer, 1957), and in the Canadian Rockies (Kobayashi, 1938). At several of these localities a number of species of olenid-like trilobites are associated with the assemblages of the *Dunderbergia* faunizone and in Nevada also with the *Elvinia* faunizone trilobites. Their appearance in these assemblages marks the lowest stratigraphic occurrence of olenids in western North America (Wilson, 1957, fig. 2). *Glyptagnostus*, a characteristic "Atlantic province" agnostid, also appears in these assemblages.

In the Appalachians *Aphelaspis* is unknown from any miogeosynclinal sites; but an assemblage of the *Aphelaspis* faunizone does occur in the Nolichucky shale from the outer edge of the cratonic biofacies realm. At the central Appalachian localities (Text-fig. 13) the interval between the top of the *Crepicephalus* faunizone and the base of the *Elvinia* faunizone is occupied by barren beds, 250 feet of massive dolomite (Stacy member) overlain by 400 feet of cyclically alternating dark silty dolomite, orthoquartzite, shaly dolomite, massive black dolomite, and dolomitic cryptozoon stromatolite (lower sandy member of Gatesburg formation) (Wilson, 1952). Nor has any indication of these faunizone assemblages been discovered in the northern Appalachians.

The *Elvinia* faunizone assemblage is believed to have been of western derivation. The Komaspididae, the Dokimocephalidae and a new genus aff. *Housia* (Drewes & Palmer, 1957) appear in the *Dunderbergia* faunizone of Nevada. The Komaspididae are represented by the subgeneric form of



TEXT-FIG. *13*—Upper Cambrian Intermediate Realm in central Appalachians. (From published work by Wilson and Tasch with editing and revision by Wilson.)

Irvingella-Parairvingella—which has essentially the cephalic structure of typical *Irvingella* but still retains the narrow preglabellar area and anterior border furrow of the ancestral genus, *Komaspis*.

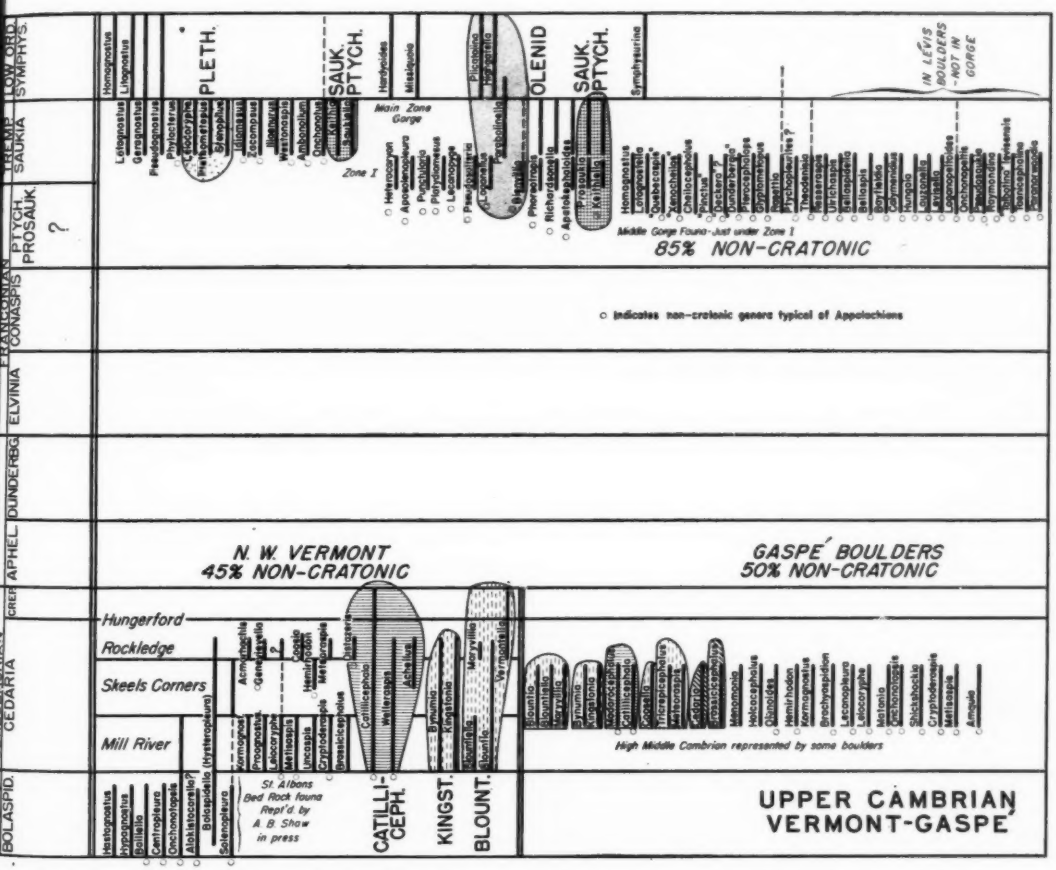
In the central Appalachians the easternmost sites containing the *Elvinia* faunizone occur in central Pennsylvania—Ore Hill limestone—and east central New York—the Potsdam and Galway formations. The faunas from these localities are fairly large and are characteristic of the cratonic biofacies realm. To the south the Conococheague of the Shenandoah valley carries a small assemblage of seven genera belonging to the intermediate biofacies—the *Pseudosaratogia magna* fauna. Five of the genera are of extracratonic origin and are known elsewhere only in the *Elvinia* assemblage from the Ore Hill limestone. To the north the allochthonous beds east of Logan's Line from Vermont through eastern Pennsylvania have been searched thoroughly at many localities, but no trace of this intermediate biofacies assemblage has been found. It is possible that there was no sedimentation on the miogeosyncline in the northern Appalachians during the entire early Franconian.

Evidence of the *Conaspis* faunizone in the miogeosynclinal areas is very slight—a complete enigma since the Parabolinoididae, the characteristic family of the zone in the cratonic realm, is believed to have been derived from olenid-like trilobites of extracratonic origin. In the Cordilleran region

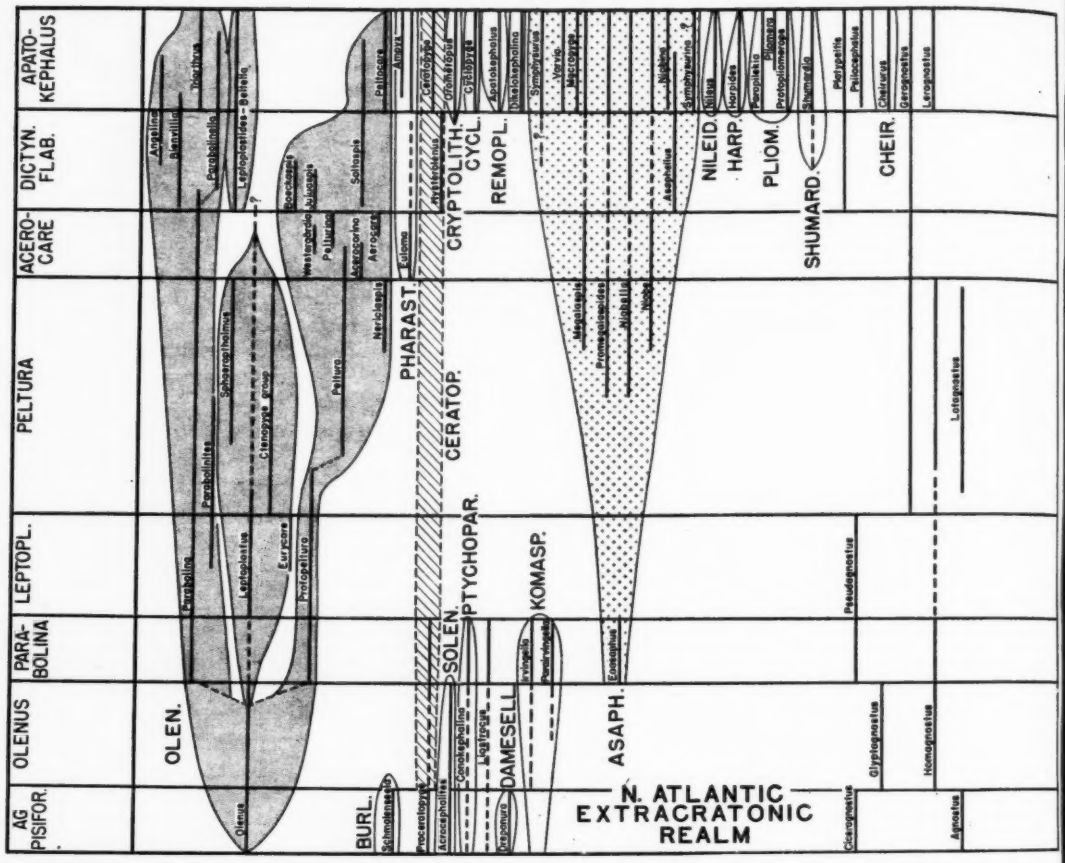
the beds at this position are usually dolomitic and unfossiliferous. The only known occurrence of the faunizone was recently reported (Drewes & Palmer, 1957) from limestones in the southern Snake River Range, Nevada. Only *Pseudagnostus*, *Billingsella* and an undet. conaspid trilobite were found and no trace of the Parabolinoididae.

In the central Appalachians traces of the faunizone were found by Wilson (1951) in the top of the Ore Hill limestone of central Pennsylvania. The fauna consists of three typically cratonic genera and two extracratonic genera, *Olenaspella* and "*Conaspis*" *retractalabra* (Text-fig. 13). In the Conococheague of the Shenandoah valley two extracratonic genera are associated with *Pseudosaratogia magna* in beds above the typical development of that faunule. Wilson (1957, fig. 3) believes that a *Pseudosaratogia magna* faunizone may be the Appalachian intermediate biofacies equivalent of both the *Elvinia* and the *Conaspis* faunizones.

The *Ptychaspis-Prosaukia* and the *Saukia* faunizones of the cratonic realm are apparently replaced in the intermediate realm by the *Hungaia magnifica* faunal assemblage. The middle Gorge formation of the Vermont slate belt and the Clarendon Springs dolomite and Hoyt formation on the eastern border of the Adirondacks, as well as exotic boulders in the Ordovician shales at Lévis contain a large fauna of about 60 genera, 85% of which are apparently non-cratonic



TEXT-FIG. *14*—Upper Cambrian Intermediate Realm, Vermont and Gaspé. (From published work of Rasetti and Shaw, and from unpublished work by Shaw and Gilman with editing and revision by Shaw.)



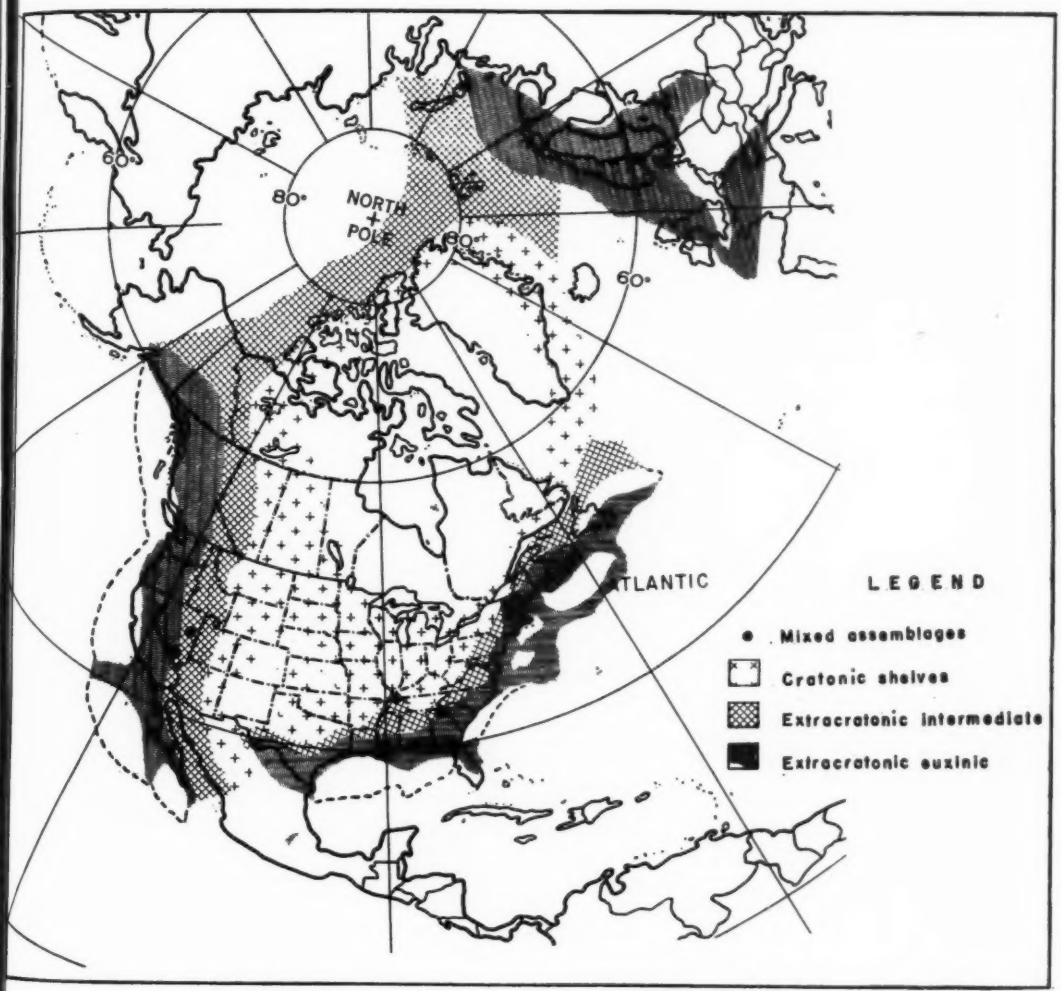
TEXT-FIG. *15*—Upper Cambrian Euxinic Extracratonic Realm, North Atlantic (two upper zones are Tremadocian-Lower Ordovician). (From published work by Westergaard and Henningsmoen and Tremadocian faunal lists by Henningsmoen.)

in origin. This fauna has seven genera which somewhat resemble trilobites of the *Elvinia* faunizone, and fourteen genera which occur elsewhere in late Upper Cambrian beds or range into the Lower Ordovician. Three of the genera, *Loganellus*, *Bienvillia* and "*Parabolinella*" have olenid affinities.

In the Cordilleran intermediate realm Palmer (in Nolan, et al., 1956) has reported the *Hungaia magnifica* assemblage from the Windfall formation, Eureka district, and from the Tybo and Yucca Flats districts (Palmer, 1956) in southeastern Nevada. At these localities the assemblage appears in the sections almost immediately above the *Elvinia* faunizone. Two olenid genera, *Bienvillia* and *Tostonia*, are associated with this western assemblage. A hundred miles to the east in the Snake River Range (Drewes & Palmer, 1957) limestones of the *Elvinia* faunizone are overlain by limestones carrying faunas assigned to the *Conaspis* faunizone and to the middle *Saukia* faunizone. Since the stratigraphy of the Eureka, Tybo and Yucca Flats sections shows no evidence of a disconformity at this level, it could be assumed that the ecologic conditions of the intermediate biofacies to which the *Hungaia* assemblage was adapted actually were established in the western miogeosynclinal areas of the Cordilleran region soon after *Elvinia* zone time, and prevailed there during all of upper Franconian and Trempealeauan time.

In the Marathon uplift of west Texas a small exotic boulder from the Woods Hollow Ordovician shales contains *Richardsonella* (Wilson, 1956) suggesting the presence of the *Hungaia* assemblage in the intermediate realm to the south.

In the northern Appalachian region because of the absence of any late Dresbachian or early Franconian assemblages and the complicated structure of the Late Cambrian beds, the stratigraphic position of the *Hungaia* assemblage can only be estimated from the faunal affinities. As previously stated a number of the characteristic genera of the fauna appear upon the shelf areas of the central United States in the middle *Saukia* faunizone. That the invasion was from the southern and eastern extracratonic realms is indicated because at least eight of these genera occur in the Llano uplift sections, while not more than three or four are known in Missouri and the Croixan area. This occurrence has led the eastern *Hungaia* assemblage to *appear* most nearly the stratigraphic equivalent of late Franconian and early Trempealeauan faunal assemblages of the cratonic realm. It is, however, quite possible that in Appalachian miogeosynclinal



TEXT-FIG. *16*—Location of Upper Cambrian Biofacies Realms.

sites the environmental conditions favorable to the *Hungaia magnifica* fauna immediately succeeded the range of the *Pseudosaratogia magna* assemblage.

Lower Ordovician (Canadian) Biostratigraphy

Faunas of the Cratonic Biofacies.—The early Canadian seas spread relatively rapidly across the reliefless coastal plains far into the interior of the continent. The carbonate depositing environment of the intermediate biofacies stretched from the Cordilleran and the Appalachian regions into and through the length of the Mississippi valley. The cratonic biofacies was restricted to narrow bands around the shores of Laurentia (Oneota of Wisconsin and Gailor of the Adirondacks) and the scattered banks of the interior (deposits of the Ozarkian section and the Ellenburger). The carbonate shoals were dominated by the well-known cephalopod-gastropod facies. Many Late Cambrian trilobite genera were incapable of making the required adjustments, and only genera of the Plethopeltidae and *Bienvillia* survived the changes. The ptychoparoid stock responded once more with the development of the Hystricuridae, and *Clelandia* and related genera. These few genera in association with several early and very characteristic Asaphidae (*Symphysurina* and *Bellefontia*) comprise the very limited cratonic assemblages of the earliest Ordovician.

Faunas of the Extracratonic Biofacies.—The distribution of the succeeding Lower Ordovician extracratonic assemblages is a striking continuation of the Cambrian pattern. In the Cordilleran region the miogeosynclinal areas are expanded and their faunas show an intimate mixture of cratonic and extracratonic elements. To the west of these areas characteristic sediments of the "Atlantic province"—the graptolite shales —are now known and in them typical "Atlantic province" Tremadocian trilobite assemblages are found but are as yet largely undescribed. Ross (1951) and L. F. Hintze (1952) described from the carbonate sections of Utah and eastern Nevada what may be regarded as a typical intermediate biofacies assemblage.

To the west in the lower 300 feet of the Goodwin limestone in the Antelope Range of central Nevada, 25 miles southwest of Eureka, Hintze reports the "Atlantic province" genus *Parabolinella;* and J. M. Greene (1955) finds *Parabolinella* and *Tostonia?* from the same limestones in the Monitor Range, 50 miles southwest of Eureka. Merriam (Nolan, et al, 1956) has also obtained *Kainella* and *Diplapatokephalus finalis* in the lower third of the Goodwin of the Antelope Range. This association would indicate that *Parabolinella* of the extracratonic euxinic biofacies appeared in the intermediate biofacies at the stratigraphic position of Ross and Hintze's Zone D (*Kainella-Leiostegium*).

Trilobites are known in the graptolite shales and dark limestones of the allochthonous Vinini formation of the Great Basin but have not been studied.

The best known intermediate biofacies assemblages of Tremadocian age in western North America have been described by Kobayashi (1955) from the McKay group of British Columbia, in the western Canadian Rockies immediately east of the Rocky Mountain trench. The McKay group comprises several thousand feet of dark argillaceous limestone and shale. The assemblages contain a number of genera in common with those of Utah and Nevada, but these are associated with genera either known from the "Atlantic province" faunas or showing marked affinities with genera from that biofacies (*Kainella, Apatokephalus, Asaphellus, Beltella* (*Paenebeltella*), *Peltura, Sphaeroph-thalmella, Parabolinella, Eulomella, Jujuyaspis* and a Nileidae). Kobayashi correlates these assemblages with the zones of Ross and Hintze. At the base the *Symphysurina* beds are equivalent to Zones A through C; and the succeeding *Robsonoceras?-Apatokephalus* beds and the *Kainella-Evansaspis* beds are equivalent to Zones D and E. These zones, comprising more than 1,500 feet of the lower McKay, are of Lower Tremadocian age in terms of the South American sequence (Harrington and Leanza, 1957).

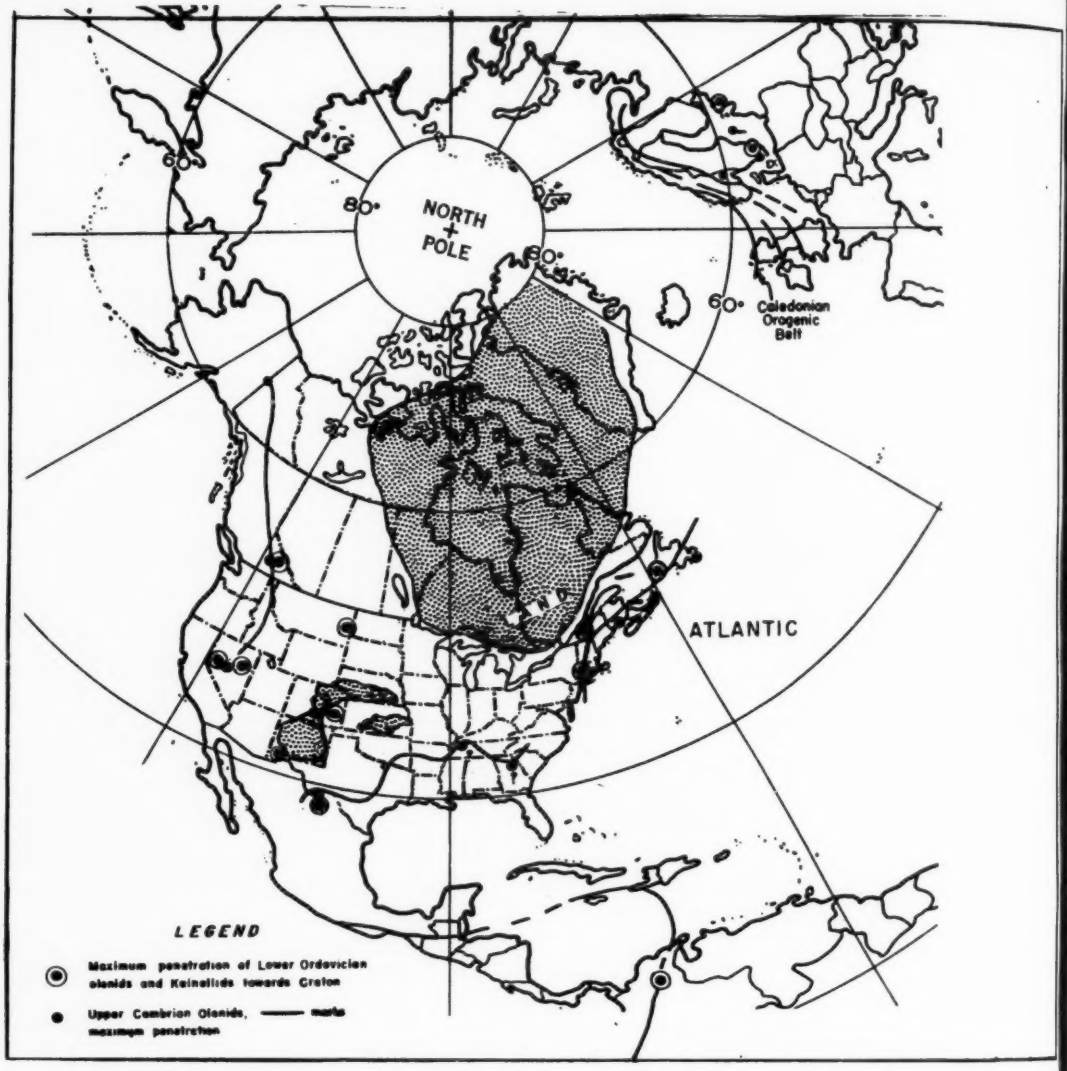
Ross (1957) describes several Canadian faunas from wells in the Williston Basin, Montana. The lowest assemblage, *Kainella, Leiostegium,* hystricurids and *Imbricatia,* correlates with the Ross and Hintze Zone D, and indicates the mixing of cratonic and

extracratonic elements. All the higher assemblages are predominately extracratonic. Graptolites, *Bryograptus* and *Dictyonema*, are associated with *Asaphellus*, *Kirkella*, *Kayseraspis*, *Apatokephalus*, *Megalaspidella*, *Ogyginus*, and *Lloydia?*. These higher faunas show strong affinities with those of the McKay group and like them also with the Argentina Tremadocian assemblages.

The presence of extracratonic assemblages of Canadian age overlapping former cratonic sites can also be traced across southwestern United States where the same fortunate mixing of Tremadocian and Gasconadian faunal elements occurs. *Kainella* is known in situ in argillaceous strata in the Hatchet Mountains of southwest New Mexico at the top of Gasconadian beds of the El Paso formation (R. H. Flower, personal communication, 1957); from cherty limestone near the base of the Manitou formation in Williams Canyon, Colorado (Maher, 1950); and also in an exotic boulder from the Marathon (Wilson, 1954a). In the Marathon region of west Texas Wilson (1954a, 1956) has obtained *Rasettia* and *Symphysurina* (cratonic genera) associated with fragmentary specimens of *Parabolinopsis*, *Beltella*, *Apatokephalus*, *Kayseraspis*, *Parabolinella* and *Shumardia*, both in exotic boulders and in situ strata.

A comparable mixing of early Canadian cratonic and extracratonic (Tremadocian) faunal elements occurs in collections in the northern Appalachians from Newfoundland to southern Vermont and adjoining eastern New York. Rasetti (1954a) described from the thin, gray limestones interbedded with pale green graptolite shales of the Green Point formation at Broom Point, Newfoundland (Schuchert and Dunbar, 1934) the olenids, *Bienvillia* and *Leiobienvillia*, with *Borthaspidella* and *Pareuloma*. *Pareuloma* and *Borthaspidella* with *Shumardia* were obtained from dark gray limestone beds associated with graptolite shales at Cap des Rosiers, Gaspé. The Lévis shales at Quebec contain in situ Tremadocian faunas as well as trilobites from the exotic boulders which have been described by Rasetti (1943) who lists *Symphysurina*, *Leiostegium*, *Pilekia*, *Kainella*, *Diplapatokephalus*, *Onchonotus*, *Hardyoides* (syn. *Levisaspis*), and *Loganopeltis*. To the south in the slate belt of Vermont Shaw (1951, 1955) reported a similar mixed fauna from thinbedded limestones of the Highgate formation. This fauna is most interesting in its association of *Symphysurina* with *Hardyoides*, *Missisquoia* and the olenid genera *Plicatolina*, *Highgatella* and *Parabolinella* typical of the extracratonic euxinic biofacies. *Plicatolina* is known from the Tremadocian of Argentina (Harrington and Leanza, 1957); *Highgatella* and *Symphysurina* occur in basal Canadian shales in the Little Rocky Mountains, Montana (Lochman and Duncan, 1950—lowermost fauna); and *Missisquoia* is reported in the lowest Canadian zone of the Ellenberger formation of the Llano Uplift of Texas, and is the only member of the fauna known to have penetrated the cratonic realm. Still farther south Lochman (1956b) figured a specimen of *Parabolina* from a limestone lense in black shales of the Taconic sequence of eastern New York. And to the east Hutchinson (1952) records from the McLeod Brook formation of Cape Breton Island a typical Tremadocian assemblage of the extracratonic euxinic biofacies. The formation consists largely of light grey micaceous shales with local beds of black shales and contains *Dictyonema flabelliforme*, *Asaphellus*, *Niobe* (*Niobella*) and *Shumardia*.

Of particular significance is the fact that the Canadian occurrences of extracratonic trilobite assemblages lie farther toward the craton on both sides of Laurentia than do those of the Cambrian extracratonic faunas (fig. 17). An excellent example is found in the cores from the Williston Basin (Ross, 1957). The assemblages suggest that in this area a cratonic biofacies dominated the sites during the initial deposition of the basal Ordovician, Hintze and Ross Zones A–C, and that typical cratonic genera, *Symphysurina*, *Bellefontia*, *Hystricurus*, were present. However, as the cratonic realm moved into the interior, it was succeeded in this area by the ecologic conditions of the intermediate realm, and extracratonic genera appear in ever-increasing numbers. Ross's lowest assemblage can be confidently correlated with Zone D because of the similarity of assemblage with those occurring in western Utah and Nevada. In the higher faunas graptolites appear and olenid and asaphid genera from the extracratonic euxinic realm.



TEXT-FIG. *17*—Maximum penetration of Olenids and Kainellids towards the Craton.

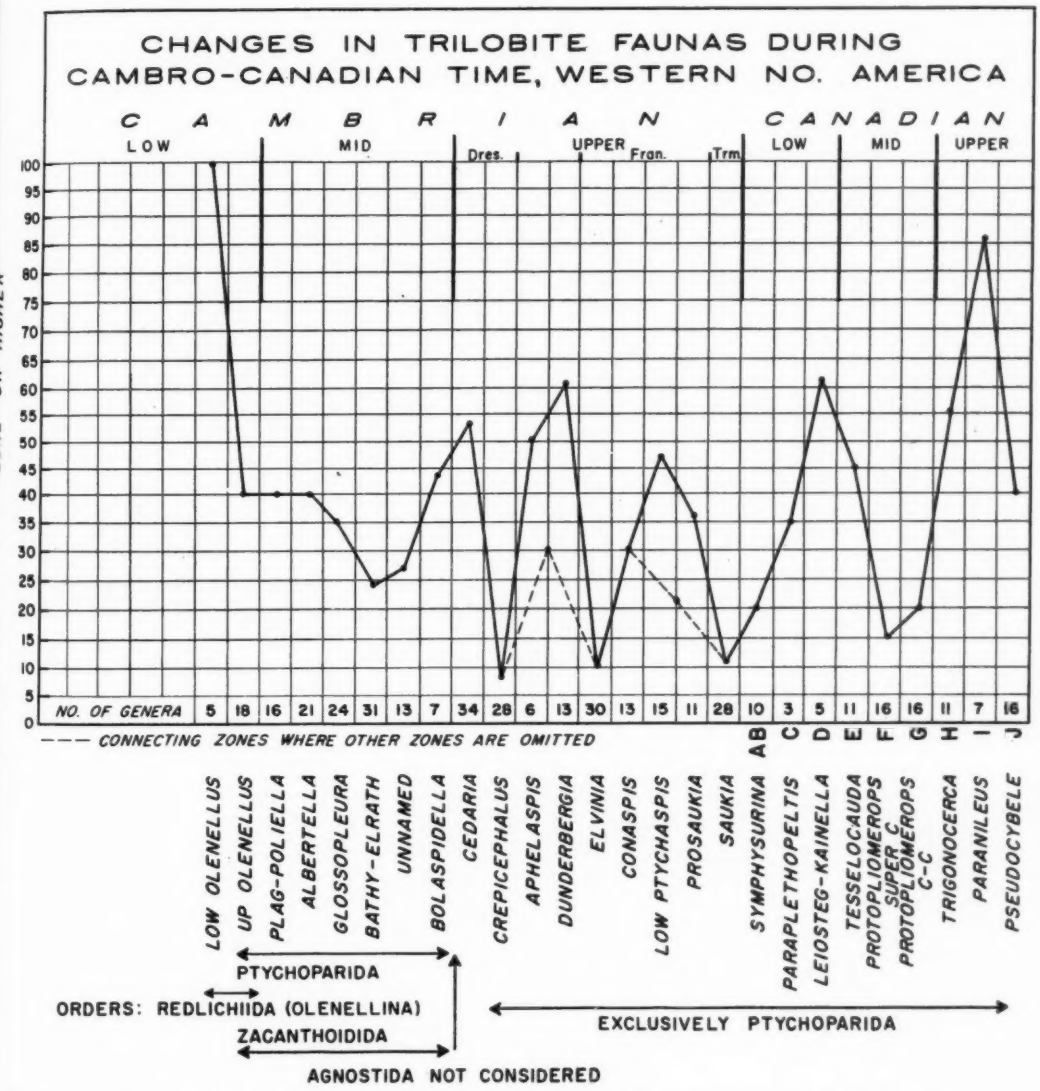
The assemblages listed by Kobayashi (1955) although frankly of mixed composition from the intermediate realm, nonetheless, also show a steady increase higher in the section of genera having extracratonic euxinic affinities.

The faunal evidence is substantiated by the lithofacies evidence. On the outer edges of the miogeosyncline an argillaceous lithofacies becomes increasingly conspicuous until typical graptolite shales appear in the sections. In the Cordilleran region and in Newfoundland where mapping has been sufficiently detailed, it can be shown that the clastic sections thicken westward (Glen Ogle-McKay group) or eastward, respectively, i.e. always in the eugeosynclinal direction. This pattern suggests that the initial (earliest Paleozoic) cratonward movement of the mobile belts encircling the Laurentian craton culminated in the Canadian with a cratonward thrust or pulse. In re-

sponse to this pulse, all the belts (with their characteristic lithofacies and biofacies) moved interiorward. The miogeosyncline areas and the intermediate biofacies realm were markedly broadened, while the cratonic belt and shallow shelf biofacies became restricted to relatively narrow bands around the continent and the scattered shoals of the interior.

SIGNIFICANT CHANGES IN CAMBRO-ORDOVICIAN TRILOBITE FAUNAS

The number of trilobite genera which range from the preceding faunizone into the succeeding assemblage was examined by percentages as a clue to the position of really significant faunal changes. This tabulation (fig. 18) is believed to contribute important data regardless of the fact that the



TEXT-FIG. *18*—Changes in Trilobite Faunas during Cambro-Canadian time, western North America.

percentages are obviously affected by the available size of the faunas, the degree of thoroughness of the descriptive work done upon them, and the geographic location of the collections. All assemblages from the cratonic and Cordilleran intermediate biofacies realms are included on the chart. A rigid geographic segregation by realms or subdivisions of realms would materially affect the percentage values.

For the Lower Cambrian the 100% at the beginning of the column means only that all the early Olenellid genera continue on into the late Lower Cambrian, in fact, most of them to the end of the period.

At the beginning of the Middle Cambrian there is a drop in percentage of genera continuing from the Lower Cambrian which does reflect the extinction of the Olenellidae. But had the table been constructed before Rasetti's 1951 publication on the Canadian Rocky Mountain assemblages there would have appeared a sharp, almost total faunal break at this level. Sedimentation occurred during earliest Middle Cambrian only in the intermediate realm. The *Plagiura-Poliella* assemblages from these beds document the gradual evolutionary change of the primitive Ptychopariidae across this boundary.

We believe that a value of 45–60% for the change in composition from one faunizone assemblage to the next probably represents the true value for normal evolutionary growth of trilobite assemblages in a stable biofacies realm—the gradual extinction of genera of the more primitive families being effected and thus counterbalanced by biotic pressure from the potentially nascent genera of the more progressive families, such as the Alokistocaridae. However, at two postions in the Middle Cambrian the percentage falls. Both drops are not in response to true faunal changes but are a reflection of limited descriptive work on the assemblages of the succeeding faunizones, the *Glossopleura* and the unnamed at the top of the Middle Cambrian. For this table, only the *Glossopleura* assemblages of the United States and Canada were considered. This incompletely known fauna can be compared with the much larger *Glossopleura* fauna of the intermediate realm described from Sonora, Mexico (Lochman in Cooper, et al., 1952). This Mexican assemblage materially increases the number of known genera and if it had been used the percentage of genera continuing into the next zone would have been considerably higher. At the top of the Middle Cambrian the assemblages of the Park and correlative formations are still largely undescribed with the exception of a small suite of genera from the very top, the *Bolaspidella* subzone, which contains genera continuing up into the base of the *Cedaria* faunizone. The relatively small percentage of continuing genera in the unnamed zone is probably incorrect.

The value rises again to a normal 45–50% for the Dresbachian *Cedaria-Crepicephalus* faunizones, confirming the suspected continuity of evolutionary development during this time under continuing stable ecologic conditions.

The sudden drop between the *Crepicephalus* and *Aphelaspis* faunizones is real and equally drastic in intermediate and cratonic biofacies. It can only reflect drastic ecologic changes although the sections do not generally show important sedimentation changes at this level. When the cratonic realm alone is considered, there is a 70% change (30% continuing genera) between the *Aphelaspis* and *Elvinia* assemblages; but this percentage value reflects the widespread break in sedimentation over the craton at this position and the absence of the *Dunderbergia* faunizone. However, higher percentage values of continuing genera occur from *Aphelaspis* to *Dunderbergia* and from *Dunderbergia* to *Elvinia* (50 to 60%) in the Cordilleran intermediate realm where the evolutionary development of the Pterocephalidae continued unbroken and primitive elements of the *Elvinia* assemblage began to make their appearance. The percentage values for the *Aphelaspis* to *Dunderbergia* and *Dunderbergia* to *Elvinia* faunizones may rise as the assemblages from these zones in the Great Basin region are described.

The drop between the *Elvinia* and *Conaspis* faunizones is real and again must reflect drastic ecologic changes over the intermediate and cratonic realms. The Parabolinoididae dominate the assemblages, but *Conaspis* and *Wilbernia* also appear. The 30% of continuing genera from *Conaspis* to the *Pty-*

chaspis-Prosaukia faunizone signifies not a general continuity of family evolutionary development from the preceding zone, but rather a gradual shift back to and stabilizing of the usual (or normal) ecologic conditions. This is reflected by the return of the Komaspididae, the progressive dwindling of the Parabolinoididae, and a steady increase in genera of the conaspid stock. The percentage of continuing genera from the *Ptychaspis* subzone to the *Prosaukia* subzone and from the *Prosaukia* subzone to the *Saukia* zone are about in the normal 40 to 50 per cent range. In the Cordilleran sections where elements of the *Hungaia* fauna appear in the higher Franconian, 56 per cent of the total genera occur higher in the *Saukia* zone. Basically the *Saukia* assemblages are characterized by the continued evolution of families of the conaspid stock from the *Prosaukia* subzone, and the continued presence of such genera as *Monocheilus* and *Rasettia* through the lower half of the zone. In middle *Saukia* faunizone time, with the invasion of the extracratonic genera of the *Hungaia* fauna, the *Saukia* assemblages take on a more distinctive appearance.

The sharp drop in percentage value at the Upper Cambrian-Canadian (Tremadocian) boundary is real as far as our present knowledge of cratonic and intermediate assemblages is concerned. At many of the cratonic sites there is a break in sedimentation which has served to emphasize the faunal changes. In the intermediate realm it is probable that sedimentation was continuous across this boundary. However, the faunas at this level from the intermediate realm are as yet poorly known, so that the percentage value on the table actually reflects the cratonic conditions only.

The data for the Canadian part of figure 18 are taken from work by Ross (1951) and Hintze (1952) on the faunas of the Cordilleran region. Such figures can be better compiled by specialists in Ordovician faunas and other Ordovician regions should be considered before conclusions are drawn. Notwithstanding, it seems evident that a real and important faunal change occurs in ptychoparoid trilobite faunas between Middle and Upper Canadian time, and that this may be repeated between the Canadian and Chazyan.

CONCLUSIONS

The basic reason for the distinctness of the "Atlantic" and "Pacific" province faunal assemblages during the Cambrian and Tremadocian is believed to be the contiguous existence of three biofacies realms oriented concentrically with respect to the continent—Laurentia. Recent discoveries of elements of the "Atlantic" assemblages in the far western Cordilleran region, and of assemblages of mixed composition on the southern and eastern border of North America as well as in the Cordilleran region, has rendered untenable the earlier hypothesis that the assemblages had evolved independently on opposite sides of an unbroken land barrier.

The "Pacific province" assemblages occupy shelf and unstable shelf sites of the craton—the cratonic biofacies. The "Atlantic province" assemblages occupy sites radially farthest removed from the Laurentian continent, areas influenced by the oceanic environment and termed the extracratonic euxinic biofacies. In the intervening sites, faunas of all degrees of mixing may be found —the intermediate biofacies. In so far as our present knowledge of the sediments and tectonism characteristic of each of these realms permits, the probable ecologic conditions controlling each biofacies are reconstructed.

The accepted faunal units of late Lower Cambrian, Middle Cambrian and the Dresbachian stage do not have sharp boundaries. Rather they show the gradual evolutionary development of one trilobite assemblage into the next younger assemblage across gradational levels. Only in the Upper Cambrian, beginning with the *Aphelaspis* faunizone, do assemblages of vertically well-segregated genera bounded by sharp faunal breaks appear in the column. This phenomenon is most characteristic of, though not unique for, the faunas of the cratonic realm. It is believed caused by the occurrence of relatively sudden and drastic ecologic changes within the cratonic and intermediate biofacies realms. These changes are thought to have been basically controlled by tectonic movements of major importance throughout the northern hemisphere. This relationship can, at present, be partially demonstrated.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 351–356, PLS. 44–45, 1 TEXT-FIG., MARCH 1958

CRETACEOUS AMMONITES FROM THE SPILLWAY EXCAVATION OF CEDAR BLUFF DAM, TREGO COUNTY, KANSAS

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ABSTRACT—This paper contains the description of some Cretaceous ammonites from the Cedar Bluff Dam spillway excavation, Trego County, Kansas, the locality of which is now not accessible. The ammonites are *Collignoniceras woolgari* (Mantell), *Proplacenticeras* cf. *P. pseudoplacenta* (Hyatt), *Scaphites patulus* Cobban, and *Scaphites* cf. *S. larvaeformis* Meek & Hayden, indicating the zone of *Collignoniceras woolgari* of Turonian age. The upper limit of the zone in Kansas is defined as the lower Blue Hill shale.

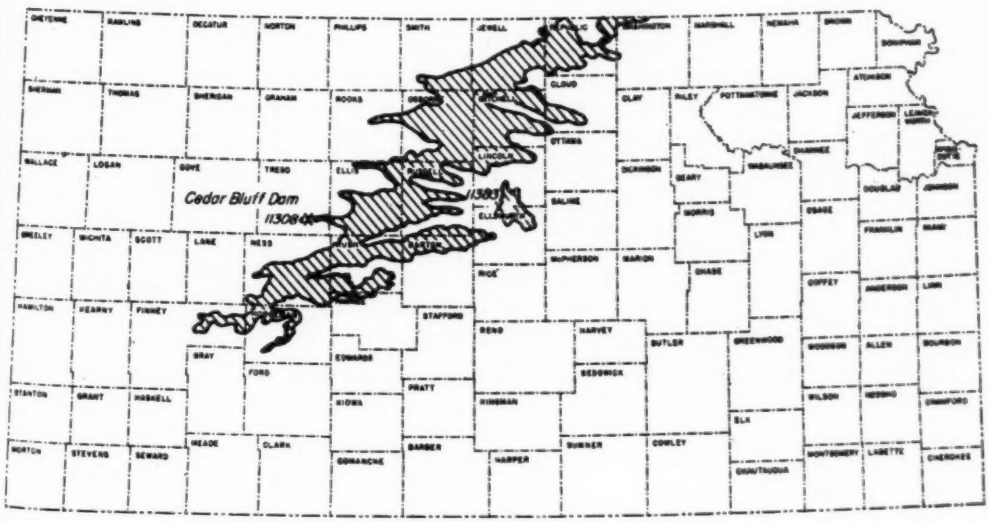
INTRODUCTION AND ACKNOWLEDGMENTS

IN THE course of studying the Cretaceous fossils of Kansas, the authors examined several specimens of ammonites from the spillway excavation made during the construction of Cedar Bluff dam, Trego County, Kansas, in 1950 to 1952. The fossil locality is now inaccessible, and fossils from the corresponding zone in other parts of Kansas have rarely been found, hence the fossils discovered from this locality should be recorded.

The principal purpose of the senior author during his visit to the United States is to study the general taxonomy of Cretaceous ammonites and the interregional correlation of Cretaceous strata. The faunule from the Cedar Bluff Dam area is one of the sources used for world-wide correlation with the Kansas section. The specimens from other localities in Kansas are mentioned in this paper for comparison with those from Cedar Bluff Dam.

MATERIAL

The specimens described came from near the bottom of the spillway excavation of the Cedar Bluff Dam, Trego County, in the W½, sec. 36, T. 14 S., R. 22 W., Kansas (Text-fig. 1) and are now preserved in the



TEXT-FIG. 1—Index map showing location of Cedar Bluff Dam (KU. 11308) and a new locality (KU. 11383) of *Collignoniceras woolgari* (Mantell). Ruling indicates outcrop area of Carlile shale in Kansas.

TABLE 1—CHEMICAL ANALYSIS OF CARBONATE CONTENT OF BLUE HILL AND FAIRPORT SHALE

	(1) Cedar Bluff	(2) Blue Hill	(3) Fairport
Percentage of carbon dioxide (CO_2)	2.66	2.02	21.30
Percentage loss on ignition in air to 600°C.	11.49	9.76	8.07

Analyst: R. T. Runnels, State Geological Survey of Kansas, 7/29/57.

Museum of Invertebrate Paleontology, the University of Kansas (KU), and in the Fort Hays Kansas State College Museum (FHM). They were presented to us by the discoverers, Dr. L. D. Wooster (KU) and Mr. Kenneth Teater (FHM). The Cedar Bluff Dam locality is designated as Kansas University register no. 11308 and it is recorded in the Fort Hays State College Museum as "near the bottom of the spillway excavation of Cedar Bluff Dam, 35 feet below the surface."

The Cedar Bluff Reservoir is surrounded by the escarpment of the Fort Hays limestone and is underlain by the Carlile shale. The exposed Carlile shale consists of the Blue Hill shale member at this outcrop. The authors estimated from measurements made recently that the surface of the spillway is 125 feet below the base of the Fort Hays limestone. The thickness of the Blue Hill shale member is estimated to be 200 feet in Russell County (Moore, and others, 1951, p. 24). There is a gradual thinning of the member from Russell County (200 ft.), to Hamilton County (75 ft.) in the western extremity of Kansas, and the Cedar Bluff locality is much closer to Russell County than to Hamilton County. Therefore, the fossiliferous rock of the spillway excavation is thought to be within the lowermost 50 feet of the Blue Hill shale.

To confirm this conclusion, the authors selected three samples of shale for chemical analysis of the percentage of calcium carbonate. The samples are from (1) Cedar Bluff Dam spillway excavation (KU. 11308), (2) Blue Hill shale member (upper Carlile fm.) containing *Collignoniceras hyatti* (Stanton), *Scaphites carlilensis* Morrow, *Inoceramus flaccidus* White, etc. (NW¼, sec. 24, T. 7 S., R. 14 W., Osborn County, Kansas), and (3) Fairport shale member (lower Carlile fm.) (KU. 10546, NE¼, sec. 36, T. 4 S., R. 8 W., Jewell County, Kansas.

Because of the lithological character of the fossiliferous rock from the spillway excavation at the Cedar Bluff Dam the locality is assigned to the Blue Hill shale. The rock is dark bluish-grey, nearly black when wet, clayey, and less calcareous than the rocks of the Fairport member of the Carlile formation.

Fossils are abundant in the shale and do not occur in nodules as do specimens of *Collignoniceras hyatti* in the main part of the Blue Hill shale member. Most are secondarily flattened, but the whitish shell substance, although altered, is preserved, and external molds are clearly impressed on the planes of stratification. Sutures can be seen on the internal molds of some specimens, despite their crushed condition. The exceptional state of preservation may be a result of the freshness of the rock, which was excavated deep below the surface. From usual surface outcrops of shale of the Carlile formation in Kansas, fossils in this state of preservation are rarely obtainable. Thus, the collection represents an unusual occurrence and should be recorded.

In addition to the ammonites described, fish scales and *Inoceramus* were found. But they are crushed or so fragmentary that they cannot be accurately identified. To determine the relative age of the fossils from the Cedar Bluff Dam locality, the authors visited other localities in Kansas, where similar assemblages of species are found.

EXPLANATION OF PLATE 44

All specimens ×1 except *1*, which is ×2/3.

FIG. *1–6*—*Collignoniceras woolgari* (Mantell). *1*, FHM. 2777; *2*, FHM. 10236; *3*, FHM. 10237, a specimen having closely spaced fine ribs; *4*, FHM. 10239; *5*, KU. 11308, a specimen having weak ribs in some places; and *6*, KU. 11308, a coarsely ornamented specimen. *2–6* are ×1. All from Cedar Bluff Dam spillway excavation, Trego County, Kansas.

1

2

3

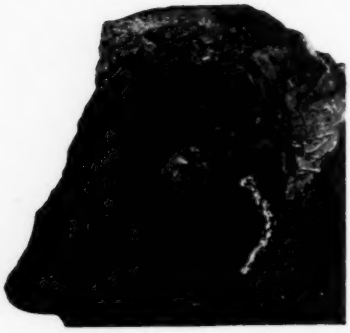
4

5

6

1

2



3

4

5a

5b

The specimens of previous collections deposited in the University of Kansas have also been studied for comparison with those of the localities the authors visited.

The authors are indebted to Professor Raymond C. Moore of the University of Kansas, Dr. Frank C. Foley, Director of the State Geological Survey of Kansas, and Mr. George F. Sternberg, Curator of Fort Hays Kansas State College Museum, for facilities they have provided for the study. Mr. Robert J. Mann has kindly assisted the authors in the field as well as in the laboratory; Miss Judy Smith assisted in printing photographs; Mr. R. T. Runnels made chemical analyses of the shales; Dr. W. A. Cobban and Dr. Donald E. Hattin have given the senior author opportunities to discuss with them fossils from the Carlile shale. This paper is a partial result of study during a visit by the senior author to the United States under the auspices of the Conference Board of Associated Research Councils.

PALEONTOLOGICAL DESCRIPTIONS

COLLIGNONICERAS WOOLGARI (Mantell)
Pl. 44, figs. 1–6; Pl. 45, fig. 1

This species occurs abundantly at the Cedar Bluff dam locality. It is represented by numerous specimens of various sizes. Small ones are most numerous, the intermediate sizes less so, and a few fragments of the large body whorl are preserved in the Fort Hays State College Museum. Inasmuch as the specimens of intermediate size less than 200 mm. in diameter are wholly septate, the smaller ones are probably immature.

No single specimen shows all the diagnostic features of the species perfectly. A synthesis of the diagnostic features of several of the better preserved specimens, however, leaves no doubt of the reference of the specimens to *Collignoniceras woolgari* (Mantell).

The characteristic features are moderately evolute whorls, serrated ventral keel, prosiradiate ribs of equal length without intercalation of secondary ribs, clavate outer ventrolateral tubercles and distinct conical inner ventrolateral tubercles on each rib of the inner whorls, horned ventrolateral tubercles on the outer whorl, asymmetric serration on the keel opposite each rib, sloping more steeply forward than backward, and sutures of the Collignoniceratidae type.

Haas (1946) pointed out the wide variations of *Collignoniceras woolgari* (Mantell). This was confirmed by subsequent authors (e.g. Cobban, Rohrer, & Erdmann, 1956). Similarly, the specimens from the Cedar Bluff Dam show variation.

Some of the smaller specimens have curved, fairly fine, closely spaced ribs and small nodes (Pl. 44, fig. 3). One of the smaller specimens (diameter 35 mm.) in the collection of Kansas University (Pl. 44, fig. 6) has straight, strong, widely spaced ribs with strong tubercles on the outer whorl. Another specimen (Pl. 44, fig. 2) shows intermediate features in strength, spacing, and curvature of ribs, and strength of tubercles. A larger specimen (FHM. No. 2777), (about 200 mm. in diameter) is septate even near its anterior end, and on its preserved portion of one and a half whorls, has widely spaced, strong, straight ribs and prominent marginal tubercles (Pl. 44, fig. 1). The large marginal knobs on this specimen have on their summits clavate outer ventrolateral tubercles and conical inner ventrolateral tubercles, although the two lesser tubercles (ventrolateral) tend to be united in more mature portions of the shells. A fragment of a still larger whorl

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EXPLANATION OF PLATE 45

All figures are natural size.

FIG. *1*—*Collignoniceras woolgari* (Mantell). External mold of a coarsely ornamented specimen, KU. 11273, Horse Thief Canyon, Hodgeman County, Kansas, gray chalk of lower part of Fairport shale member, Carlile shale.

2—*Proplacenticeras* cf. *P. pseudoplacenta* (Hyatt). Lateral view. FHM. 10240, Cedar Bluff Dam spillway excavation, Trego County, Kansas, probably lowest part of Blue Hill shale member, Carlile shale.

3–5—*Scaphites patulus* Cobban. *3*, Lateral view, KU. 11273, the same locality and bed as *1*. *4*, KU. 11308, the same locality and bed as *2*; *5a* and *5b*, another specimen (external mold and internal cast) from the same locality, KU. 11308.

TABLE 2—MEASUREMENTS OF *Collignoniceras woolgari*

Specimen	Diameter mm.	Height mm.	Umbilicus mm.	(%) rated increase
FHM. 2777	197.5	70.0	76.0	(38)
FHM. 10236	31.2	10.7	13.0	(40)
FHM. 10237	25.5	8.9	10.5	(41)
FHM. 10238	40.0	14.3	16.4	(41)
FHM. 10239	31.2	11.7	11.0	(35)
KU. 11308	ca. 68.5	24.0	30.0	(43)
KU. 11273	41.4	16.4	16.4	(39)
KU. 10546	43.0	17.7	15.0	(35)

(FHM. No. 10235) is very strongly ribbed, and the outer and inner ventrolateral tubercles are united with the horn. These relatively strongly ornamented examples are similar to the typical specimens as described by Sharpe (1855) in England and by Meek (1876) in North America.

Although the ribs are principally of equal length and strength, a few relatively weak ribs are found on parts of some specimens (Pl. 44, fig. 5). This feature may foreshadow the characteristic unequal development of rib strength found in *Collignoniceras hyatti* (Stanton), which occurs in the main part of the Blue Hill shale member of Kansas. The keel of *C. hyatti* is more nearly continuous and less distinctly serrate than the keel of *C. woolgari*.

This species also shows a considerable variation in shell-form. The following measurements were taken from more or less crushed specimens, but the figures may be useful to give some idea of variation in the size of umbilicus and rate of increase of whorl-height.

In addition to the specimens from Cedar Bluff Dam (loc. KU. 11308) there are other specimens of this species in the University of Kansas collections from the following localities (the locality records are mainly from the register book of the Museum of Invertebrate Paleontology of the University, but the authors assume all responsibility for the identification of the species).

KU. 11273, Horse Thief Canyon, Hodgeman County, Kansas: lower part of Fairport member, grey chalk, along with *Scaphites patulus* Cobban. Coarsely ribbed specimen

KU. 10532, NE¼, sec. 8, T. 15 S., R. 20 W., Ellis County, Kansas: middle part of Fairport member, with *Inoceramus* aff. *I. latus* Sowerby. Finely ribbed specimen (D. E. Hattin coll.)

KU. 10546, NE¼, sec. 36, T. 9 S., R. 8 W., Jewell County, Kansas: middle part of Fairport member, with *Inoceramus* aff. *I. latus* Sowerby. Finely ribbed specimen (D. E. Hattin coll.)

KU. 10548, NW¼, sec. 32, T. 11 S., R. 15 W., Russell County, Kansas: chalk bed in basal part of Fairport member, with *Inoceramus cuvieri* Sowerby. Coarsely ribbed specimen (D. E. Hattin coll.)

KU. 10549, SE¼, sec. 6, T. 12 S., R. 15 W., Russell County, Kansas: chalk bed in basal part of Fairport member. Poorly preserved, comparable to above specimen, associated with *Inoceramus* cf. *I. cuvieri* Sowerby and *Inoceramus* aff. *I. labiatus* Schlotheim (D. E. Hattin coll.)

KU. 10536, NE¼, sec. 8, T. 15 S., R. 20 W., Ellis County, Kansas: middle-upper part of Fairport member. Poorly preserved specimens (D. E. Hattin coll.)

KU. 11383, center N½, sec. 22, T. 14 S., R. 8 W., Ellsworth County, Kansas: "Fencepost limestone" at top of Greenhorn formation. Three smaller specimens along with abundant specimens of *Inoceramus* aff. *I. labiatus* Schlotheim (transitional to *I. latus* Sowerby) and *I. cuvieri* Sowerby (T. Matsumoto, H. W. Miller, and R. J. Mann coll.)

Rubey & Bass (1925) and Bass (1926) have already reported (J. B. Reeside's identification) the occurrence of *Collignoniceras woolgari* (Mantell) in various parts of the Fairport shale member of the Carlile formation in Russell and Hamilton Counties, Kansas. We have not seen their collections, however, as they did not mention the repositories of the specimens. The present authors obtained specimens indicating that the species ranges not only throughout the whole Fairport shale member but also up into the lowest part of the Blue Hill shale member and down into the uppermost portion of the Greenhorn formation in parts of Kansas.

Cobban, Rohrer & Erdmann (1956) gave a short discussion of the widespread occurrence of the species in the Western Interior Region of the United States.

PROPLACENTICERAS cf. P. PSEUDOPLACENTA (Hyatt)
Pl. 45, fig. 2

Two specimens from the spillway excavation of Cedar Bluff Dam are preserved in the Fort Hays State College Museum. The external suture-lines are exceptionally well preserved on one secondarily flattened specimen (FHM. 10240). The other specimen (FHM. 10241) shows small tubercles at the umbilical margin of its body whorl. Falcoid growth-striae are visible on the flank on parts of both specimens.

Although accurate identification is difficult, the species from this locality resembles *Proplacenticeras pseudoplacenta* (Hyatt, 1903) in many features. In the collections of the University of Kansas and Fort Hays State College Museum there are examples of this species from the zone of *Collignoniceras hyatti* in the main part of the Blue Hill shale member of the Carlile shale that are better preserved. They show a considerable range of variation in sutures, distinctness of umbilical tubercles, ratio of height to breadth of whorls, width of venter, serration of the ventral keels, etc. The characters also change ontogenetically. To clarify the true state of variation and ontogenetic change of this species and its relationships with other allied species, more taxonomic work will be required. It should be noted, furthermore, that the smaller probably immature shells from the Blue Hill shale member have widely spaced weak crescentic riblets on the outer half of the flank.

The Cedar Bluff Dam specimens probably fall within the variation of *Proplacenticeras pseudoplacenta* (Hyatt). The less complicated sutures, absence of tubercles at the mid-flank, and presence of small umbilical tubercles and crescentic riblets on outer parts of the sides permit the species to be referred to *Proplacenticeras* Spath rather than to *Placenticeras* Meek.

Proplacenticeras (or *Placenticeras*) has not been reported previously from the zone of *Collignoniceras woolgari* in Kansas. This occurrence is reasonable, however, as *Proplacenticeras pseudoplacenta* (Hyatt) and its allies appear in the Britton member of the Eagle Ford formation in Texas (Hyatt, 1903; Moreman, 1942; T. Matsumoto's field observation in 1957).

SCAPHITES PATULUS Cobban
Pl. 45, figs. 3–5

In the collection at Kansas University are two specimens of this species from loc. KU. 11308 (Cedar Bluff Dam) and another specimen from loc. KU. 11273, Horse Thief Canyon, Hodgeman County, Kansas. The latter specimen is from the lower part of the Fairport member, Carlile shale, and is associated with *Collignoniceras woolgari* (Mantell).

Although no measurements on secondarily deformed specimens are accurate, they give some idea of the size relationship and of variation in numbers of ornaments, and are therefore useful.

The specimens show a relatively rounded or oval shell outline, a narrow space between the curved part of the living chamber and the septate whorl, 6–10 strongly tuberculate primary ribs and 21 to 26 secondary ribs on the body whorl, rursiradiate ribbing on the last septate whorl, nearly equal spacing of the ventral ribs, and relatively simple sutures.

The broadness of the whorl could not be measured. All other characters agree with the diagnosis of *Scaphites patulus* Cobban (1951). Therefore, the specimens are best referable to that species.

TABLE 3—MEASUREMENTS OF *Scaphites patulus* COBBAN

	Length mm.	Height mm.	Breadth mm.	Diameter of septate whorl mm.	Number of ribs on body whorl	
					Primary	Secondary
(1)	32.0	23.5	—	21.0	8 (7?)	16 (7?)
(2)	36.2	32.9	—	26.3	7	26
(3)	33.5	29.8	—	24.0	6	21 (22?)

(1) and (2) from KU. 11308; (3) from KU. 11273.

Cobban's types were found in the lower part of the Carlile shale in the Black Hills, along with *Collignoniceras woolgari* (Mantell), *Scaphites larvaeformis* Meek & Hayden, and "*Inoceramus fragilis* Hall & Meek."

SCAPHITES cf. S. LARVAEFORMIS Meek and Hayden

This species is represented by a poorly preserved specimen in Fort Hays Kansas State College Museum (10242). There is another specimen in the collection of the University of Kansas (loc. KU. 4920), but the locality information is incomplete (Benton group, Kansas).

This occurrence of *Scaphites larvaeformis* is, however, quite reasonable as it is associated with *Collignoniceras woolgari* and *Scaphites patulus* in the lower Carlile shale of many other areas in the Western Interior Region.

CONCLUSION

(1) The ammonites from the spillway excavation of Cedar Bluff Dam, Trego County, Kansas are *Collignoniceras woolgari* (Mantell), *Proplacenticeras* cf. *P. pseudoplacenta* (Hyatt), *Scaphites patulus* Cobban, and *Scaphites* cf. *S. larvaeformis* Meek & Hayden.

(2) The assemblage of species indicates the zone of *Collignoniceras woolgari*.

(3) Stratigraphically the fossiliferous rocks probably belong to the lowest part of the Blue Hill shale member. Other records mentioned in the paleontological descriptions indicate that the zone covers the whole of the Fairport shale (lower) member, of the Carlile formation. There is, furthermore, evidence that suggests the lower limit of the zone of *Collignoniceras woolgari* in Kansas is in the uppermost portion of the Greenhorn limestone. The range is similar to that in other parts of the Western Interior Region, such as described by Cobban, Rohrer, & Erdmann (1956).

(4) From the above facts, it can be generally stated that the boundary of rock units in different areas is not always coincident with that of biostratigraphic zones. Further stratigraphic and paleontologic analysis is needed at various localities before accurate range limits can be determined.

(5) The specimens of *Inoceramus* from the Cedar Bluff Dam locality are too poorly preserved to be specifically identified. They are comparable to the species associated with the ammonite faunule of the *Collignoniceras woolgari* zone. However, that form could be called *Inoceramus* aff. *I. latus* Sowerby. Another species *Inoceramus cuvieri* Sowerby, which also seems to be characteristic of the zone, was found by the authors at other localities. The type of *Inoceramus fragilis* Hall & Meek is very probably an immature specimen of *I. cuvieri* Sowerby. A detailed discussion of the species of *Inoceramus* will be presented in another paper by the senior author.

(6) The zone of *Collignoniceras woolgari* in the Western Interior Region of North America can be correlated with the zone of *Terebratula lata*, middle part of the Turonian, in the English Chalk, which also contains *C. woolgari* and *Inoceramus cuvieri*.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 357–361, 4 TEXT-FIGS., MARCH 1958

A NEW GENUS AND SPECIES OF PERMIAN OPHIUROID FROM KANSAS

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ABSTRACT—A new genus and species of ophiuroid (*Ophiuraster burrisi* Miller) is described from the Americus limestone (lower Permian) of Kansas. No ophiuroids have been described previously from the Permian of North America. *Ophiuraster* seems to be more nearly allied to the Mesozoic and Cenozoic ophiuroid groups than to ophiuroids previously found in the Paleozoic and is assigned to the family Ophiolepididea.

INTRODUCTION

OPHIUROIDS are extremely rare as fossils and have not been found previously in Permian rocks of North America. Weller (1930) described three types of ophiuroid vertebral ossicles (fused ambulacral plates) from the Pennsylvanian of Illinois and Indiana, and stated that they were the first ophiuroid remains to be found in the Pennsylvanian of North America. Inasmuch as only vertebral ossicles were found, Weller did not name the fossils, although they were previously undescribed.

Schuchert (1915) monographed the Paleozoic starfish fauna of North America but did not record any known Paleozoic species from rocks younger than Mississippian age.

Paleozoic ophiuroids are grouped into classes or subclasses separate from those of the Mesozoic and Cenozoic ophiuroids, although Matsumoto (1917) classified some Paleozoic species with Mesozoic and Cenozoic ophiuroids in his subclass Myophiuroida.

The ophiuroid vertebral ossicles described by Weller (1930) are distinguished from those of Mesozoic and later ophiuroids, in that the Paleozoic species have the radial canals completely encased within the two fused vertebral ossicles. Mesozoic and later species carry the radial canal in a groove underneath the vertebral ossicles.

Acknowledgements.—The writer is grateful to Mr. L. D. Burris, who presented the specimen to the State Geological Survey of Kansas.

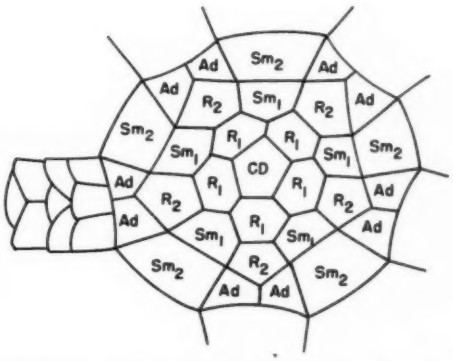
PRESERVED MATERIALS

Four specimens were preserved on a 3- by 4-inch limestone slab. Two poorly preserved specimens had the oral surface exposed and the two other specimens had the apical surface exposed. The smallest specimen was designated the holotype. This specimen was the best preserved and retained all the plates of the apical surface.

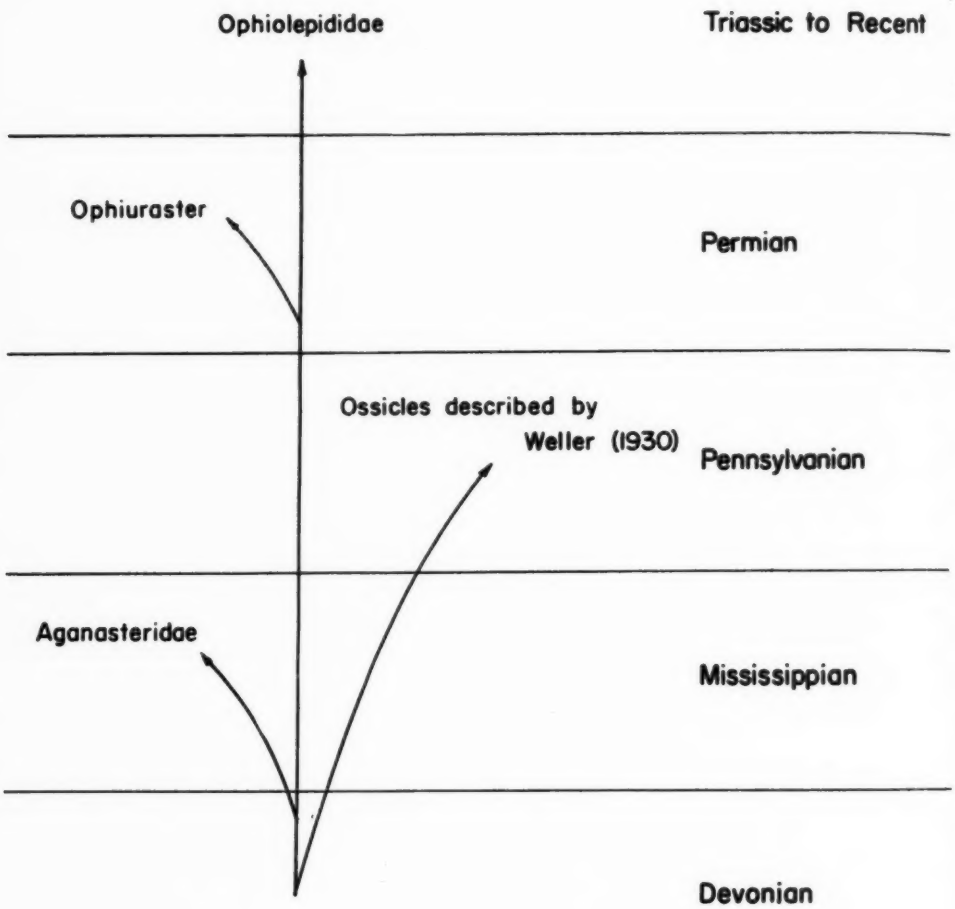
Stratigraphic Occurrence and Locality.—The specimen was found by Mr. Lue D. Burris of Augusta, Kansas, in N½ SW¼ sec. 18, T. 26 S., R. 9 E., near Reece, Kansas. The stratigraphic position is the Americus limestone member of the Foraker limestone, Council Grove group, Wolfcampian Series. The author was unable to find any additional specimens during a field trip to the locality.

Order OPHIURAE
Family OPHIOLEPIDIDEA Lyman, 1878

Cuénot (1948) characterized the family Ophiolepididea as those ophiuroids having 3 to 6 buccal spines, the aboral disk covered



TEXT-FIG. 1—Diagrammatic sketch of dorsal plates and inferred homologies of dorsal plates of *Ophiuraster*.



TEXT-FIG. 2—Possible relationship of *Ophiuraster* to other ophiuroid groups.

by plates that are relatively large, often preserving the juvenile aspect; spines short, and flattened along the length of the arm. The family ranges from the Triassic to Recent and includes about 50 genera, among which are: *Ophiura, Ophiocten, Aspidura, Ophiolepis, Ophionotus, Amphiophiura, Ophiopyrgus, Ophiomastus, Ophiomusium, Astrophiura,* and *Ophiophycis.* In many of these genera the disk is covered by large plates arranged concentrically around a centro-dorsal plate.

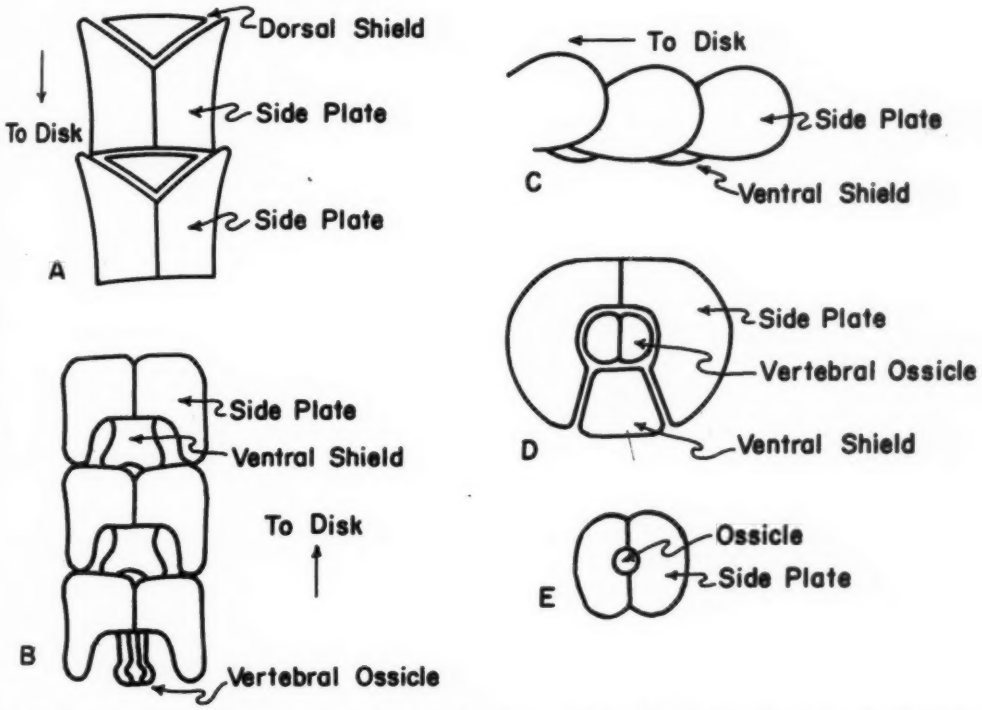
The fossil ophiuroids from the Permian of Kansas have the apical plates arranged con-

centrically around a centro-dorsal plate in the same manner as typical ophiolepidids (Text-fig. 1). Not only is the plate arrangement similar, but number and homologies of the plates also seem to be similar. Buccal parts are not identifiable on any of the Kansas specimens. The arms seem to cross the ventral surface to the mouth. In the Kansas specimens the apical plates are large and pentagonal, and they overlap.

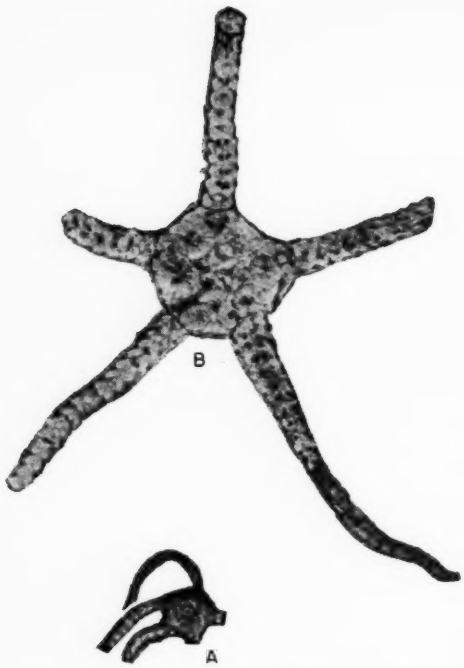
Vertebral ossicles are exposed in some of the specimens where the arm plates are broken away; the ossicles seem to have been recrystallized. The suture line between the two vertebral ossicles is distinguishable, but the hole for the radial canal cannot be distinguished with certainty in any of the paired ossicles. One arm has the ventral side uppermost (Text-fig. 3), and where the ventral arm plates are missing the ossicles have a deep groove on the ventral surface. This groove may represent the radial canal passage, and in view of this, the Kansas specimens would seem to be more nearly allied to the Mesozoic than to Paleozoic ophiuroid groups, and are referred to the family Ophiolepididea.

Genus OPHIURASTER Miller, n. gen.
Type species OPHIURASTER BURRISI Miller, n. sp.

Disk small, pentagonal, having radial (1), radial (2), paired adradial, submarginal (1), and submarginal (2) plates arranged concentrically around the centrodorsal plate (Text-fig. 1). The arms are rounded and completely covered by plates. Side plates encircle the arm and join ventrally and dorsally; small dorsal and ventral shields fill spaces at the distal end of each segment.



TEXT-FIG. 3—A, Dorsal view of arm showing side plates and dorsal shield arrangement. B, Ventral view of an arm. The bottom segment is a diagrammatic sketch of groove along base of ossicle. Ventral shield is missing from segment. C, Side view of an arm. D, Cross-section through an arm near the disk. E, Cross-section through an arm near distal end.



TEXT-FIG. 4—A, Holotype of *Ophiuraster burrisi* Miller. Dorsal view, ×3.6. B, Ventral view of a larger specimen. The ventral plates and buccal apparatus are missing. ×3.

The vertebral ossicles have a distinct median suture, and the outline of the paired ossicles resembles a cross when seen from the dorsal side. The radial canal probably lies in a deep groove on the ventral side of the vertebral ossicles. No spines are preserved on the arms, and the species may have lacked spines in life. The arms (Text-fig. 3) are flexed horizontally and vertically in the preserved specimens. *Ophiuraster* differs from *Ophiopyrgus* in that *Ophiopyrgus* lacks radial (2) plates. *Ophiomusium* and *Amphiophiura* differs from *Ophiuraster* in that they have spines on the side plates of the arms and lack radial (2) plates.

OPHIURASTER BURRISI Miller, n. sp.
Text-fig. 4A, holotype

The disk of the largest specimen is 5.5 mm. in diameter, and the disk of the smallest specimen (holotype) is 2 mm. in diameter. The largest specimen has arms about 13 mm. long, 1.1 mm. wide near the base, and 0.3 mm. wide near the tip. The disk plates tend to be pentagonal, but vary in outline. The surface of the plates is finely granular, and the plates are thin.

The side plates of the arms (Text-fig. 3) are thick and seem to be fused to the vertebral ossicles. Near the base of the arms the dorsal plates are relatively wider and longer and cover the whole dorsal surface of the vertebral ossicle, so that the side plates do not meet dorsally. This does not occur beyond the third arm segment in any of the larger specimens and does not occur at all in the holotype (smaller specimen).

The species is named in honor of Mr. Lue D. Burris of Augusta, Kansas, who discovered the type specimen and presented it to the University of Kansas Geological Museum.

Remarks.—*Ophiuraster* resembles *Aganaster* more than any other Paleozoic ophiuroid. *Aganaster* has been found in the Mississippian (Keokuk group) of Indiana and the Calciferous sandstone from the "Crangopsis" bed, Ardross, Fife, British Isles. *Aganaster* resembles the young of Recent Ophiuroidea (Spencer, 1925) and is similar in structure to modern free-moving forms. The disk of a mature specimen of *Aganaster* is covered only by radial and primary plates, and the arms are chiefly covered by lateral plates. Both Spencer (1925) and Matsumoto (1917) state that such genera are primitive in possessing an embryonic structure, but are not necessarily archetypal or ancestral to the later ophiuroids.

It seems likely that *Ophiuraster* is related to *Aganaster*, although it is not necessarily its direct descendant (Text-fig. 2). *Ophiuraster* has progressed beyond the *Aganaster* stage of development in that *Ophiuraster* has completely enclosed its arms with three types of plates, has developed adradial plates and an extra series of radial and marginal plates, and no longer has the radial canal completely encased within the fused vertebral ossicles.

Repository.—The holotype is specimen number 11382H1 in the paleontological collection of the Department of Geology, University of Kansas, Lawrence, Kansas.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 362–365, 8 TEXT-FIGS., MARCH 1958

A NEW SPECIES OF THE EOCENE ECHINOID *PERIARCHUS*

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INTRODUCTION

NO GENUS is more important in correlation of upper Eocene marine deposits in the southeastern United States than the clypeasteroid echinoid *Periarchus*. Of the many species assigned to *Periarchus* in the past, several have been referred to *Mortonella* and some, such as *P. lyelli* (Conrad) and *P. pileussinensis* (Ravenel), have been combined to form more inclusive, in some cases polytypic, species (Cooke, 1942, p. 15).

The species described in this paper was evidently originally included in *P. lyelli* by Clark & Twitchell (1915, pl. 62, figs. 1, 2). The present study, including both qualitative and quantitative analyses, has revealed some marked morphologic distinctions between this species, *P. rutriformis* Paulson, n. sp., and *P. lyelli lyelli* and *P. lyelli pileussinensis*. The biometrical analyses revealed significantly different growth ratios (Imbrie, 1956, p. 228) as well as differences in size and in other dimensions; these differences are summarized in Text-figures 1 to 3. Qualitative differences in such features as basicoronal plates are shown in Text-figures 4 to 8.

The specimens of *P. rutriformis* used in this study were collected by Dr. Grover E. Murray from the upper Eocene Castle Hayne marl in a quarry on a dirt road 0.7 mile west of Carlton, Duplin County, North Caolina. The specimens of *P. lyelli*, s.l., were borrowed from the Louisiana State University Geology Museum and were collected from the upper Eocene Moodys and Pachuta marls at Little Stave Creek, Clarke County, Alabama.

The writer is indebted to Mr. Alan H. Cheetham for suggesting and supervising this study; to Dr. H. V. Howe for the photographs used in preparing the figures of the specimens; and to Mr. D. E. Jones for assistance in the biometrical study.

SYSTEMATICS

Order CLYPEASTEROIDA
Agassiz, 1873
Family PROTOSCUTELLIDAE
Stefanini, 1924
Genus PERIARCHUS
Conrad, 1866

PERIARCHUS RUTRIFORMIS Paulson, n. sp.

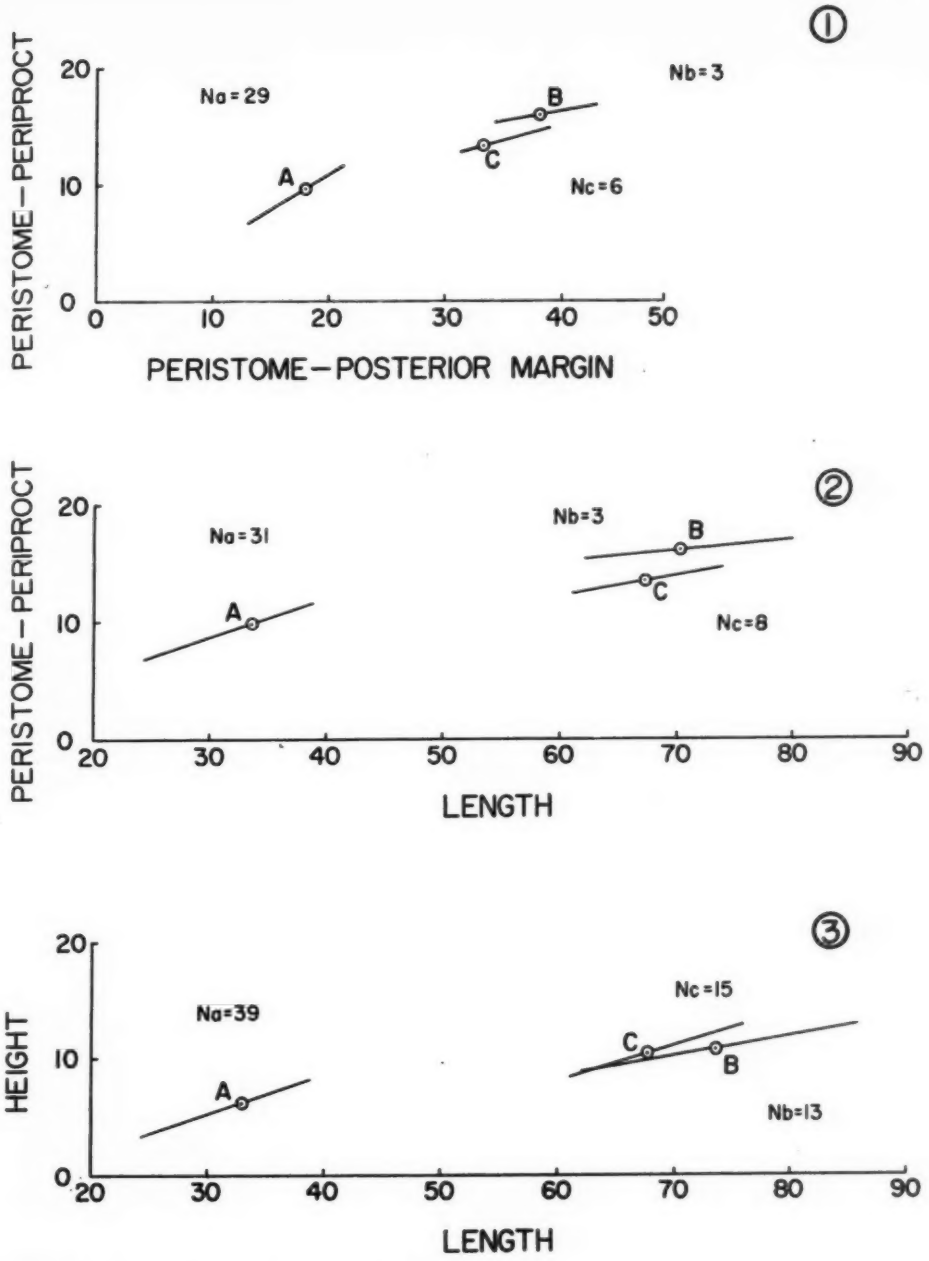
Text-figs. 5, 6, 8

Material.—Forty-six tests, holotype no. 6934 and paratypes nos. 6935 to 6939, all from Castle Hayne marl, Duplin County, North Carolina. All specimens deposited in the Louisiana State University Geology Museum.

Diagnosis.—*Periarchus* having relatively small, subovate test with two posterior indentations, food grooves which bifurcate only once, basicoronal interambulacral plates of each pair unequal, and basicoronal ambulacral plates concave on sides that join post-basicoronal interambulacral plates.

Description.—Test subovate in ambital outline, more broadly rounded posteriorly than anteriorly. Shallow marginal indentations occur in ambulacra I and V. Oculogenital system at apex of low mound which is slightly anterior to center of aboral surface and which slopes nearly uniformly to within about one third of distance to ambitus. Aboral surface between central mound and ambitus convex in anterior portion of test, slightly concave in lateral and posterior portions. Margin slightly thicker anteriorly than laterally or posteriorly. Petals three to four times as long as wide, extending about two-thirds of distance from oculogenital system to ambitus. Petals drop-shaped, widening away from apex, open at ends, having isolated primary pores. Pore-pairs within petals conjugate; outer pore of each pair elongate.

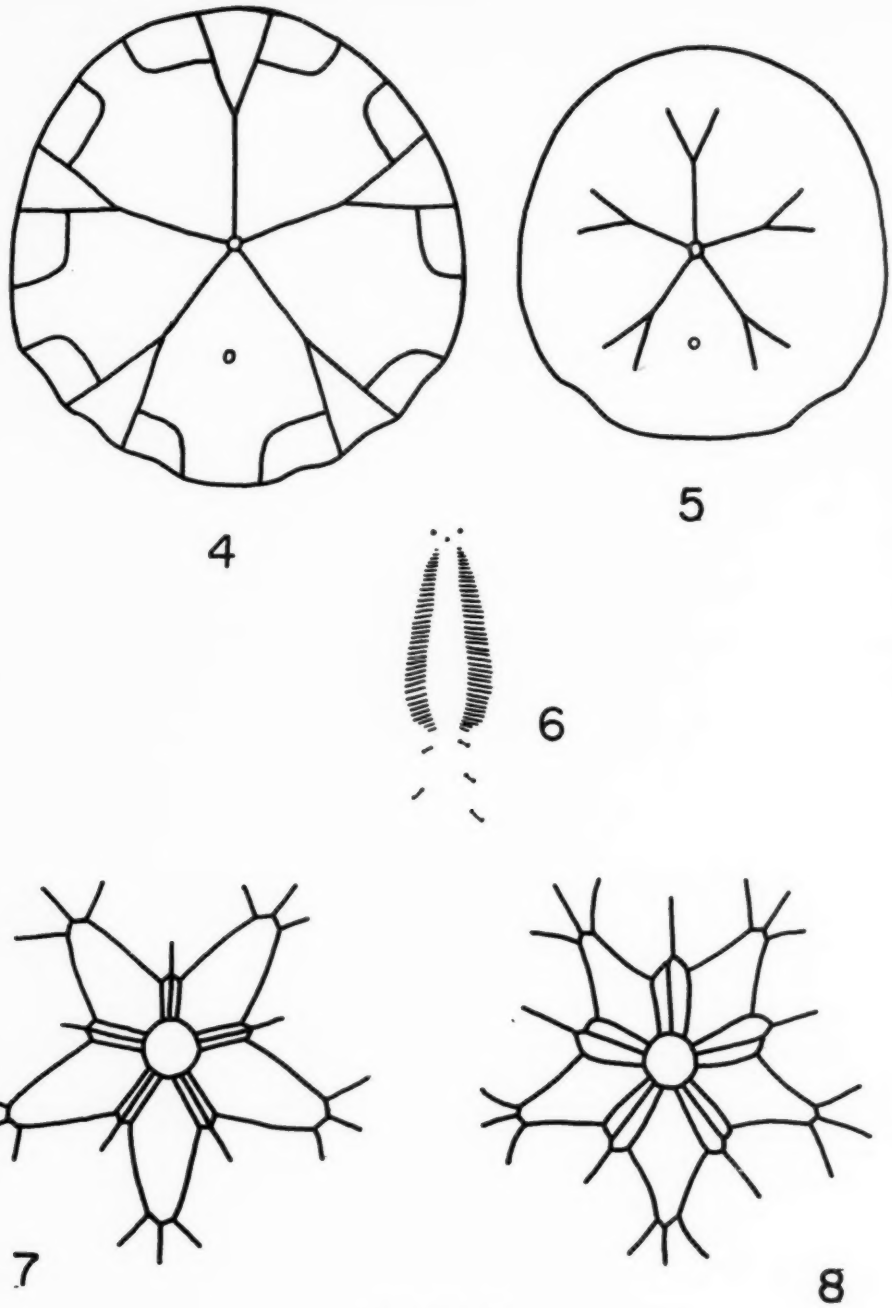
Oral surface slightly concave anterior to peristome, flat posterior to peristome. Peri-



ORDINATE AND ABSCISSA UNITS IN MILLIMETERS

TEXT-FIGS. *1–3*

A, *Periarchus rutriformis* Paulson, n. sp. *B*, *P. lyelli lyelli* (Conrad). *C*, *P. lyelli pileussinensis* (Ravenel), *N* refers to number of specimens measured and the subscript to the species measured in each case.



TEXT-FIGS. *4–8*

4,7—Periarchus lyelli pileussinensis (Ravenel). *4*, oral surface, pleisotype no. 6940, ×1.0; and *7*, basicoronal plates, plesiotype no. 6941, ×2.0.

5,6,8—Periarchus rutriformis Paulson, n. sp. *5*, oral surface, holotype no. 6934, ×2.5; *6*, petal, ambulacrum III, paratype no. 6935, ×2.5; and *8*, basicoronal plates, paratype no. 6936, ×4.0.

stome anterior to center of oral surface by two to five percent of length of test. Ambulacral food grooves bifurcate at point slightly more than half distance from peristome to ambitus or at a radius equal to distance from peristome to periproct.

One plate of each basicoronal interambulacral pair larger than the other. Basicoronal ambulacral plates concave on the sides that join post-basicoronal interambulacral plates.

Measurements.—Holotype no. 6934: length, 35.3 mm.; width, 34.0 mm.; peristome-posterior ambitus, 19.2 mm.; peristome-periproct, 11.1 mm.

Remarks.—This species differs from *Periarchus lyelli* (Conrad), s.l., its nearest known relative, in size of test, in structure of food grooves and associated indentations, and in structure of basicoronal plates.

Periarchus rutriformis is much smaller than *P. lyelli*. The largest of 46 specimens of *P. rutriformis* has a length of 38.8 mm., whereas the smallest of 30 specimens of *P. lyelli* has a length of 61.1 mm.

Periarchus rutriformis has only two indentations on the posterior margin, whereas *P. lyelli* has at least six.

The food grooves of *Periarchus rutriformis* bifurcate only once, whereas those of *P. lyelli* bifurcate twice.

In *Periarchus rutriformis* the basicoronal ambulacral plates are concave on the sides which join the post-basicoronal interambulacral plates, whereas in *P. lyelli* they are convex. In addition, the plates of each basicoronal interambulacral pair are unequal in *P. rutriformis*, equal in *P. lyelli*.

As shown in Text-figures 1 to 3, *Periarchus rutriformis* differs significantly from the two subspecies, *P. lyelli lyelli* and *P. lyelli pileussinensis*, in rates and ratios of growth of various parts of the test as well as in overall size of the test.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 366–368, PL. 46, MARCH 1958

ON THE VALIDITY OF THE OSTRACOD GENERA *GLYPTOBAIRDIA* AND *BAIRDOPPILATA*

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ABSTRACT—The shell of *Triebelina coronata* (Brady) has been studied under high magnification. This species, the designated genotype of *Glyptobairdia* Stephenson 1946, a junior synonym of *Triebelina* v.d. Bold 1946, differs from other *Triebelina* species (including the genotype *T. indopacifica* v.d. Bold) in having a series of transverse denticulations at the terminal angulations of each valve. These are not considered as part of the actual hinge. It is proposed to maintain the species in *Triebelina* until the anatomy of *Triebelina* species has been studied and to judge the validity of the fossil genus *Bairdoppilata* Coryell, Sample & Jennings, 1935, which differs similarly from *Bairdia* McCoy, 1844, in the light of the results of such an anatomical analysis. Soft parts of *T. coronata* (Brady) are available for study.

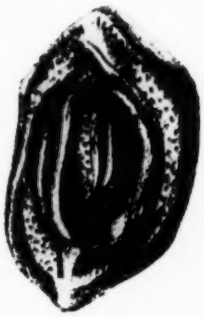
THE genus *Triebelina* was erected by v. d. Bold in 1946, *T. indopacifica* v. d. Bold, a recent species from the Malacca Straits, being designated as genotype. In the same year M. B. Stephenson erected the genus *Glyptobairdia*, for similar ornamented bairdioid forms, and designated *G. bermudezi* Stephenson, a recent Cuban species, as genotype. In a later publication Stephenson (1947) reported that he considered *Triebelina* and *Glyptobairdia* to belong to the same genus, and that the name *Triebelina* has priority over *Glyptobairdia*, since v. d. Bold's paper appeared in print a few weeks before his own. He also pointed out that Brady in 1870 described and figured a recent species from the Gulf of Mexico as *Bairdia coronata*, which undoubtedly is identical with *Glyptobairdia bermudezi* Stephenson (1946), and that this species should therefore be known as *Triebelina coronata* (Brady). A reproduction of Brady's original figure is given here, together with the first photographs of this species.

The structure of the hinge of the genus *Triebelina* has been discussed by various authors. A description of the hinge of the genotype, *T. indopacifica* v. d. Bold, was given by Germeraad (in Stephenson, 1947), and later by Triebel (1948). Very weak undivided terminal teeth are present in the right valve of this species. A similar hinge structure has been observed by Triebel (1948) in another recent species, *T. sertata;* by Stephenson (1946) in *T. howei* (Stephenson), an Oligocene species from Mississippi, and by the present author in *Triebelina boldi* Key 1955 from the ?Upper Aquitanian of France, specimens of which he was able to study.

On the other hand, Stephenson (1946, 1947) described *Triebelina coronata* (Brady) as having "strong, elongate, undivided teeth at the cardinal angles of the right valve." Triebel (1948) therefore rightly remarks that certain differences of minor importance in the structure of the hinge may be expected to occur in different species of *Triebelina*. He considered a somewhat stronger or less developed hinge of basically similar type not sufficient grounds for a sub-

EXPLANATION OF PLATE 46

FIG. *1–6*—*Triebelina coronata* (Brady.) *1*, Brady's original figure of *Bairdia coronata; 2*, outside view of left valve, ×70; *3*, outside view of right valve, ×70; *4*, hinge in the left valve, obliquely from inside below, showing crenulate bar and terminal sockets, ×125; *5*, enlarged view of the posterior part of the left valve, obliquely from inside below, showing transverse denticulation (sockets) within the overlap margin at the terminal angulation, and part of the hinge, ×210; and *6*, hinge in the right valve, viewed from above, showing terminal teeth, ×115. All Recent, St. Barts.



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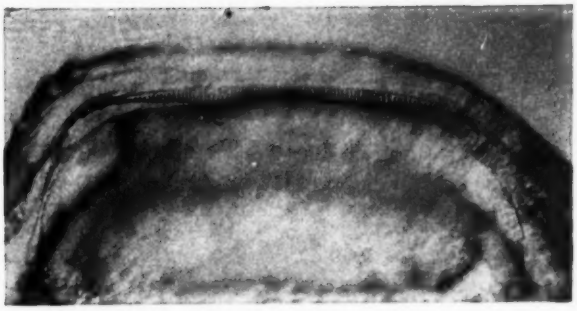

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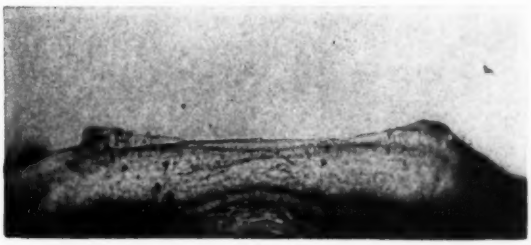

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division of the various species of *Triebelina* into two different genera.

Some time ago the author was fortunate in finding a number of very well preserved specimens of *T. coronata* (Brady) in a recent bottom sample from St. Barts, Lesser Antilles. The sample was taken in very shallow water (tidal zone) at Publico, near the town of Gustavia.

The hinge of this species was studied under high magnification, which alone permits a detailed observation of all the structural elements of ostracod carapaces. The median hinge element, which is slightly narrower in the center, is clearly crenulate (Pl. 46, fig. 4). These crenulations continue transversely over the dorsal side of the posterior and anterior teeth of the right valve, and correspondingly into the terminal sockets of the left valve. It could be established, after comparison with specimens of *Triebelina indopacifica*, *T. sertata* and *T. boldi*, that the "undivided terminal teeth" observed by Stephenson in the right valve seem indeed somewhat better developed in *T. coronata* than in these other species (Pl. 46, fig. 6). In *T. indopacifica* a very faint crenulation of the median hinge element would appear to be present, while in *T. sertata* and *T. baldi* the median hinge element seems to be smooth. However, a much more interesting and possibly important feature was discovered in *T. coronata* which seems to have escaped Stephenson's attention. Just dorsal of both the anterior and posterior angulations of the right valve, and set upon the margin of the valve are a series of small elongate teeth which fit into corresponding rows of small sockets, both anteriorly and posteriorly within the overlap margin of the left valve (Pl. 46, fig. 5). In other words, in *T. cononata* (Brady) we find an exactly similar series of transverse teeth in the right valve and matching sockets in the left one, as have been observed in a number of species formerly referred to *Bairdia*, but for which, on account of this feature, Coryell, Sample and Jennings in 1935 erected the separate genus *Bairdoppilata*.

None of the other species of *Triebelina*, which the author has studied, showed any traces of these above described transverse series of teeth and sockets at the ends of the valves, and the question which immediately arises, of course, is whether the presence of this feature in *T. coronata*, warrants the separation of this species from the genus *Triebelina*, and the accommodation of it in a separate genus. If so, this genus would again have to be named *Glytobairdia* Stephenson 1946, of which *T. coronata* was the designated genotype. If not, it would then also seem unwarranted to maintain the genus *Bairdoppilata* which has been erected for species that differ from true *Bairdia* ones only in this particular similar feature.

In the opinion of this author, the above described peculiar dentition at the posterior and anterior angulations of the valves in *T. coronata*, and the similar ones in species now classed under *Bairdoppilata* should not be regarded as part of the actual hinge. They lie a considerable distance below the line of the hinge-mechanism, along which the valves open and close, and in an opened carapace they must be completely disengaged and take no part in keeping the valves together. The true function of this structural element is not known, and is difficult to guess at the moment.

In view of the marked similarity in all other major shell features of *T. coronata* with the genotype of *Triebelina*, e.g. *T. indopacifica*, and with those of other known species of this genus, it is considered advisable, for the time being, to maintain *T. coronata* within the genus *Triebelina*. A study of the anatomy of the soft parts of *T. coronata* and *T. indopacifica*, which has so far not yet been undertaken, will eventually show whether these two species, which are both living in recent seas, really belong to different genera or not. The validity of the genus *Bairdoppilata*, of which so far apparently only fossil species have been described, could be judged in the light of the results obtained from such a biological study.

This case clearly shows the undesirability of erecting new ostracod genera for recent species based solely on a superficial examination of the empty valves, and it illustrates how a detailed study of recent ostracod species may help to determine the true generic affiliations of fossil forms. A study of the soft parts of *T. coronata* (Brady) will very probably establish beyond doubt that *Triebelina* belongs in the family *Bairdiidae*, in which it has been provisionally placed on its

shell structure. It is less certain that the anatomy of *Triebelina* species would show their generic separation from the genus *Bairdia* to be warranted also on account of their soft parts.

Many specimens of *T. coronata* obtained from the sample from St. Barts contain soft parts. The author himself does not feel competent to study those, but he urgently invites specialists in this field to undertake an anatomical investigation of this interesting species, and he will be pleased to provide specimens upon request.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 369–382, 12 TEXT-FIGS., MARCH 1958

PALEONTOLOGICAL NOTES

A CHITINOUS ANAPTYCHUS FROM THE PENNSYLVANIAN OF ILLINOIS

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Illinois State Geological Survey, Urbana

ABSTRACT—A remarkably well preserved anaptychus from the middle part of the Carbondale group of west-central Illinois is described and illustrated.

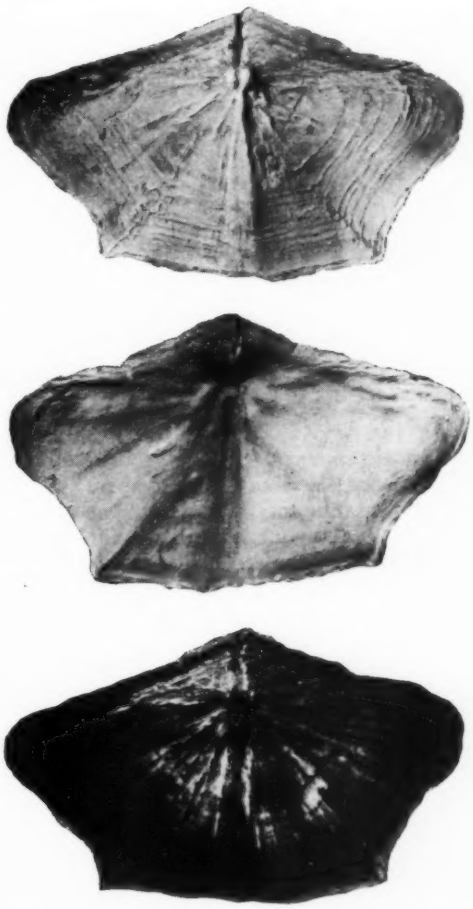
Recently, a young amateur fossil collector, Dale Moore of Canton, Illinois, sent a number of fossil specimens to us for identification. Among them was a perfectly preserved chitinoid anaptychus that he had collected from middle Carbondale shale in Peoria County, west-central Illinois. Paleozoic anaptychi are among the rarest of fossils and Pennsylvanian specimens are virtually unknown. Because of the uncertain taxonomic status and extreme rarity of anaptychi we are not naming this distinctive specimen.

The specimen is a single subpentagonal chitinous plate. The over-all form is that of a very depressed subpyramid with the apex located about $\frac{1}{4}$ height from the umbilical (upper) margin. Like the cephalopod that bore it, the plate is bilaterally symmetrical and is oriented with apex pointed in the oral direction.

A narrow brim, which is widest along the umbilical margin, borders the plate. The umbilical margin is interrupted by a deep narrow median notch which extends to the apex. Only the upper half of the notch is completely open, the lower half being a narrow furrow.

The outer (adoral) surface of the anaptychus is black and has a waxy luster; the inner surface is dull gray.

A number of low radial ridges extend from the apex, but most do not reach the brim. There are also two conspicuous striae that extend diagonally from the apex to the extremities of the external (lower) margin. The striae interrupt growth lines and divide the plate into three areas, a median and two lateral areas. The median area is arched slightly outward and in turn is divided by a low broad keel which extends from the apex to the middle of the lower margin. The keel is about 1 mm. wide near the apex but



TEXT-FIG. 1—Anaptychus from Pennsylvanian middle Carbondale group of west-central Illinois. *Upper*, external (adoral) view showing growth lines, radial ridges, radial striae, median keel, apex, and marginal notch; *Middle*, internal (aboral) view showing brim area and internal growth lines; *Lower*, external view in transmitted light showing brown color streaks; all ×$\frac{1}{2}$.

broadens to 5 mm. at the margin. Over-all dimensions for the anaptychus are, width 71 mm., height 43 mm. Thickness of the plate ranges from ¾ mm., near the apex, to paper-thin at the margins.

Viewed in transmitted light (Text-fig. 1 [lower]), the plate is a translucent amber color. A central area is more translucent than the outer but the entire specimen shows irregular dark brown streaks radiating from the apex. Some of the streaks coincide with external ridge lines. A few extend to the margin.

Because the anaptychus represents a single perfect specimen, we are reluctant to disfigure it for the purpose of making cross sections or analytical tests.

The specimen belongs to the private collection of Dale Moore, R. R. East Beech, Canton, Illinois, who discovered it loose in the bed of Copperas Creek near the middle of the line separating sec. 13, T. 7 N., R. 5 E. and sec. 18, T. 7 N., R. 6 E., Glasford Quadrangle, Peoria County. The specimen probably came from either the Summum or the St. David cyclothem.

Publication authorized by the Chief, Illinois State Geological Survey.

AN ADDITION TO THE HOLOTYPE OF THE CHESTER NAUTILOID *ENDOLOBUS CLORENSIS*

CHARLES COLLINSON
Illinois State Geological Survey, Urbana

ABSTRACT—An additional whorl of the incomplete holotype of *Endolobus clorensis* Collinson has been found. The previously missing portion, an outer whorl, shows the species to be one of the largest Mississippian forms known.

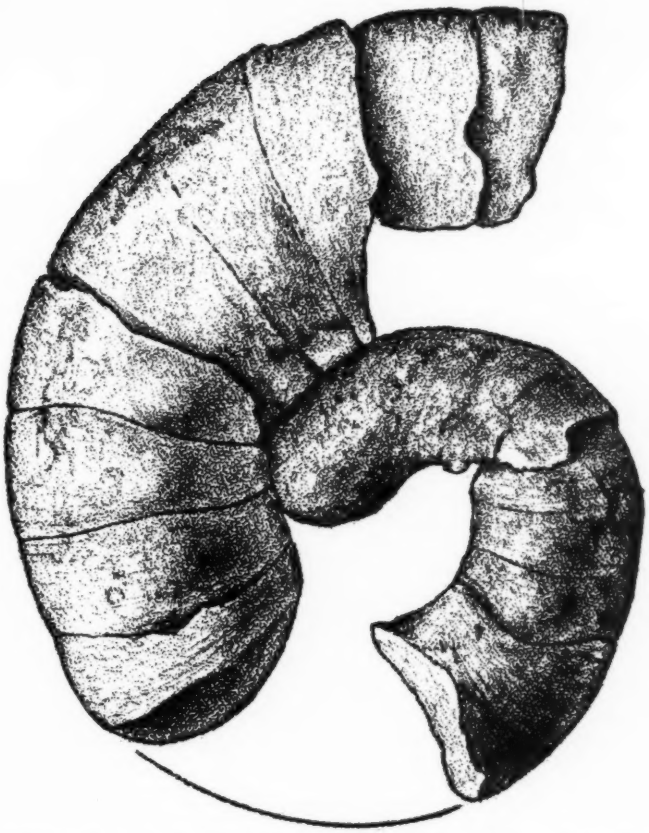
In January, 1955, I proposed the name *Endolobus clorensis* for a new species of nautiloid from the Clore limestone of western Kentucky. The species was based on a single large individual but several additional specimens have since been collected by University of Illinois field parties which annually visit the collecting locality of Walche's Cut in Caldwell County.

Among the new specimens is one of special note brought to me by Professor Harold Wanless, who collected the holotype. This specimen was collected at the same spot as the holotype and almost certainly represents part of the missing portions of the type specimen. When the two incomplete portions are fitted together, the true size of the complete holotype becomes apparent and the maximum diameter earlier estimated to be 210 mm. becomes instead 380 mm. As the holotype is completely septate, the maximum diameter during life would have been somewhat larger due to the presence of the body chamber and probably exceeded 400 mm. This size certainly places the species among the largest Mississippian nautiloids known and may well make it the largest.

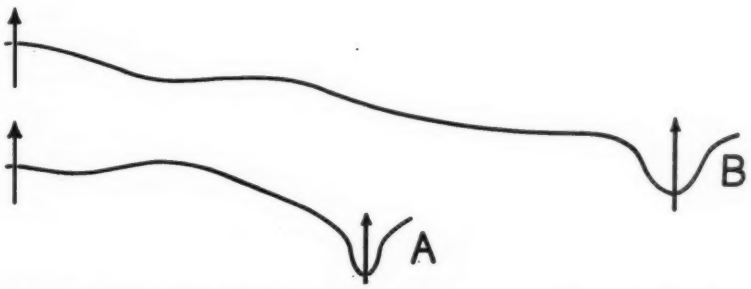
The newly discovered portion is slightly less than one half whorl and is only moderately well preserved. Nevertheless, it reveals a number of new facts about the species. In cross-section the outer whorl is more broadly rounded, both ventrally and laterally, than the inner whorl and it attains a maximum height of 148 mm. and a width of 288 mm. The siphuncle is clearly exposed in the last complete septum and measures 20 mm. in diameter. The position of the siphuncle shifted toward the venter during growth and is distinctly ventrad in the last complete septum.

In reconsideration of the portion originally described, it becomes clear that I mistook traces of internal sutures of the outer whorl for growth lines on the venter of the inner whorl. True growth lines are distinct on the outer whorl and can be seen to consist of broad, relatively deep ventral sinuses, broad, very shallow ventro-lateral salients, and similar dorso-lateral sinuses. These are connected to very shallow salients on the umbilical wall. Very shallow sinuses appear to be centered on the umbilical seam.

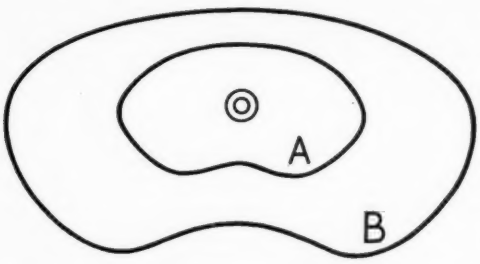
The sutures of the most orad chambers



TEXT-FIG. *1*—*Endolobus clorensis* Collinson. Lateral view of the holotype from the Clore limestone two miles northeast of Scottsburg, Kentucky. The inner whorl represents the portion originally illustrated as the holotype. The outer whorl represents the part found more recently, ×⅓.



TEXT-FIG. *2*—*Endobus clorensis* Collinson. Diagrammatic representations of (A) the most adoral suture of the inner whorl, and (B) the suture of the third from last septum of the outer whorl. Both ×¼.



TEXT-FIG. 3—Diagrammatic cross-sections of the holotype of *Endolobus clorensis* Collinson. (A) taken at oral end of inner whorl, and (B) taken at oral end of outer whorl. Both ×$\frac{1}{2}$.

are more complex than those of the inner whorl. This results from the addition of secondary ventral saddles and dorso-lateral lobes to the immature sutures. The mature sutures are somewhat variable, inasmuch as the irregularly spaced prominent lateral nodes increase the magnitude of the ventro-lateral saddle where sutures and nodes coincide. Where sutures are between nodes, the saddle is very low. There are 10 or 11 nodes per volution and they attain a maximum relief of 8 mm. on the outer volution. The camerae, which occur at a rate of 7 per half volution on the inner whorl, number 9 or 10 per half volution on the outer whorl.

It is of special interest that *E. clorensis*, which was originally known from a single specimen, may soon be considered one of the most common Chester nautiloid species. This conclusion is based not only on the number of specimens recorded by University of Illinois students but on a personal communication from Mackenzie Gordon, Jr., of the U. S. Geological Survey who has collected specimens and fragments representing eight individuals from a locality in the Fayetteville shale of Arkansas.

Publication authorized by the Chief, Illinois State Geological Survey.

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FLUORIDIZATION OF MICROFOSSILS: ADDENDA

CHARLES F. UPSHAW, ROBERT G. TODD, AND BILLY D. ALLEN
University of Missouri, Columbia

In a recent article by the writers (1957) it was intimated that the phenomenon of fluoridization of microfossils was discovered by Cookson & Singleton in 1954. It has recently come to our attention that W. Wetzel (1921) first described alteration of calcium carbonate microfossils to translucent fluorite. Wetzel stated that the altered specimens retained fine details and, at the same time, were transparent. He recommended the process to paleontologists as a preparation method for calcium carbonate microfossils. The pertinent passages of Wetzel's paper were later quoted by Seitz & Gothan (1928). Therefore, full credit should be accorded W. Wetzel for discovery of this phenomenon. In addition, the two last-mentioned works should be added to the bibliographical record of this very useful process.

We are very grateful to Dr. Curt Teichert for the foregoing information.

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CLASSIFICATION OF THECIDEAN BRACHIOPODS

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Iraq Petroleum Co., London

Thecidean brachiopods form a small and isolated group ranging in geological time from the Triassic to the present day. They have been regarded by different workers either as highly modified descendants of the Palaeozoic strophomenoids, or as extremely atypical terebratuloids. Intermediate forms between thecideans and strophomenoids or terebratuloids are not known, and the evidence from the thecideans themselves emphasizes their distinctiveness, but is not conclusive as to ancestry or relationships.

In a revision for the forthcoming "Treatise on Invertebrate Paleontology" these peculiar brachiopods are allocated subordinal rank. Due to the long delay in the publication of the brachiopod volume of this work. the opportunity is now taken to propose Thecideoidea new suborder, for the superfamily Thecideacea Termier and Termier 1949 (families Thecideidae Gray, 1840; Thecidellinidae new family, from Thecidellininae Elliott, 1953).

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MANUSCRIPT STYLE

M. L. THOMPSON
Illinois State Geological Survey, Urbana

The following Paleontological Note, *Manuscript Copy for the Journal of Paleontology*, was prepared by Drs. A. K. Miller and W. M. Furnish at my request to present examples of *Journal* style for use by prospective authors. Drs. Miller and Furnish not only have prepared innumerable manuscripts for many publications, both domestic and foreign, but also have been editors of the *Journal of Paleontology* for the Society of Economic Paleontologists and Mineralogists. They understand clearly the common irregularities that appear in authors' manuscripts, and their own manuscripts for years have been models of careful preparation.

Examples of bibliographic abbreviations of geologic literature are given by Miller & Furnish in the following Note. A list of common abbreviations has been published by the Geological Society of America in the front pages of each year's volume since 1933 of their *Bibliography and Index of Geology Exclusive of North America*. A more extensive list of abbreviations was published by the American Geological Institute in *Form of Abbreviations and Bibliographic References Commonly Used in Geological Publications*. This latter list was republished in part by Stumm & Kesling in 1957 (*Jour. Paleontology*, v. 31, p. 666).

Reprints of the following Note by Miller & Furnish, along with the text of their first paper in this number of the *Journal*, will be issued in reprint form and may be obtained by writing the Editor.

MANUSCRIPT COPY FOR THE *JOURNAL OF PALEONTOLOGY*

A. K. MILLER AND W. M. FURNISH
State University of Iowa, Iowa City

Editorial policies of scientific journals are largely matters of opinion. For the sake of uniformity and expediency, the details are settled in a more or less arbitrary manner. Also it is only natural that regulations change over a period of years. A variety of publications advise prospective authors in regard to style and procedure (*e.g.*, Warthin & Weller, 1951; Stumm & Kesling, 1957). It is hoped that a few illustrations will supplement existing instructions and help to clarify some of the usual questions; personally, we have found examples even more useful than explicit directions. In any case, no set of rules is entirely adequate, and inevitably much responsibility must rest on an author's judgment.

Contributions submitted for publication.

1. The ideal or average *Journal* article approximates some 20 to 60 typewritten pages and 1 to 4 plates. Each issue of the *Journal* contains several titles, some 500 typescript pages, and 20 or more plates. Excessively long articles may be divided into parts.
2. Short papers (usually less than 10 typewritten pages) with no more than a few simple text illustrations can logically be included in *Journal* issues as NOTES.
3. REVIEWS and NOTICES are solicited in some cases, but appropriate contributions are always in order.

Illustrations.—Figures reproduced in the *Journal* as Plates are costly; by contrast, interpretive line drawings involve even less expenditure than the printed page. Complex tables set in type are also relatively expensive and, generally, should be drafted for reproduction as zinc cuts.

Most published illustrations are thought to be adequate; moderate effort in any of several media will provide clear reliable pictures. In the past, the very best illustrations were drawings or paintings (Ridgway, 1938); even today a faithful record of all available detail can scarcely be recorded mechanically without preparation of specimen and/or picture. Any method has inherent weaknesses and will likely misrepresent some aspect of the fossil.

Magnification of illustrations should be determined discriminatingly:

1. Figures less than $\frac{1}{2}$ inch in larger dimension rarely appear to advantage.
2. Important details should be visible. Minor features can be illustrated with an enlarged view of a segment.
3. There should be some regard for relative size; in the usual case, large specimens should be depicted as larger than small ones.
4. If convenient, a uniform magnification should be employed.

Plate size was standardized in the *Journal* for several years. The $5\times7\frac{1}{2}$ inch dimension provided an overall figure about the same size as the printed page, a common rule. This size was also numerically related to the standard $8\frac{1}{2}\times11$ inch typewriter paper. As an economy move, plate area has since been increased about 25% to a $5\frac{3}{4}\times8\frac{1}{4}$ inch maximum. This larger size provides only about $\frac{1}{4}$ inch margins in bound and trimmed volumes. Authors scarcely need to be reminded that tolerances are small. Of course, plates may be submitted oversize for reduction, if proportions are maintained.

Many of the considerations in plate assembly involve aesthetic values; cost factors are also important:

1. Actual area of figures should exceed 50% of the total plate area, 47 square inches. Unless the individual pictures happen to be of uniform size, 75% coverage may appear crowded. A reasonable goal is about 60–65%.
2. Stereograms have so much to recommend them that their use may be justified; they also present problems. Economy must be sacrificed, for in most cases the required expenditure is about 2 or 3 times that of conventional illustration. In octavo-size publications more economical arrangement can result in an inconvenient displacement of

Half-page blank for heading

JOURNAL OF PALEONTOLOGY, V. 00, NO. 0, P. 000-000, PLS. 00,00, 9 TEXT-FIGS., Month Year

MIDDLE PENNSYLVANIAN SCHISTOCERATIDAE (AMMONOIDEA)

A. K. MILLER AND W. M. FURNISH

State University of Iowa, Iowa City

ABSTRACT--Triangularly coiled adolescent whorls have been described in the three more primitive genera of the Schistoceratinae. This peculiarity is most pronounced in Paralegoceras but is apparent in the ancestral Diaboloceras. Furthermore, it can be discerned in Pintoceras, a descendant. The development

TEXT-FIG. *1*—Title page with heading. About half a page should be blank above the title for heading and editorial marks.

pairs. The trained eye can visualize relief by light and shadow relationships alone. In such a circumstance, more detail can probably be observed in two carefully oriented views than in a single stereo pair.

3. As a general rule, a better "balanced" plate is secured if larger and darker pictures are arranged in the center or at the bottom. Another possible refinement is to "aim" the plates right or left, if two or more are assembled; bound margins are placed beside less important or distracting features.
4. If necessary for clarification, outlines may be projected beyond the margin of

a specimen. However, it is poor economy in plate illustration to include line drawings or to show photographs of excessive rock matrix.

5. Arrangement and numbering of figures should be logical and relatively easy to decipher. Letters, rather than numbers, are used to designate the individual parts of a text-figure.

Systematic descriptions.—The summary of critical features together with a discussion of taxonomy has become fairly well stabilized procedure over several decades. Be concise; a few words supplementary to illustration may suffice. Paleontologists should recognize an obligation and give a detailed account of geographic-stratigraphic setting. Permanent repositories, with catalogue numbers, should be recorded for all material studied.

progressively shorter and relatively wider. These internal lateral lobes are paired as septal flexures with the auxiliary (3rd to 5th lateral) lobes of the external suture, and a small additional intermediate lobe is developed on the umbilical wall.

At a conch diameter of 3 mm., there is no indication of an adventitious lobe in the first lateral saddle. However, immediately thereafter, the oral portion of the ventral flank of that saddle becomes slightly flattened (Text-fig. 8A). By a diameter of 5 mm., a distinct lobe has developed from the flattened part of the saddle (Text-fig. 8B). During later ontogenetic development, that lobe becomes relatively large and more nearly median in position within the saddle.

The occurrence of this species is given in the generic discussion. It is almost invariably rare, but we have 8 limonitic internal molds from the Millsap Lake Formation of Texas and 5 testiferous specimens from the Buckhorn Asphalt of Oklahoma. Smith (1938, p. 32) recorded a "large number" from the latter.

Genus BENDITES Miller & Furnish, n. gen.

Type species: Bendoceras moorei Plummer & Scott, 1937.

The basis for this genus is virtually a single specimen, which, as mentioned by Plummer & Scott (1937, p. 209), differs materially from all other described forms. The published data indicate that the

TEXT-FIG. 2—Page of text with systematic head. Suprageneric categories may be designated, if considered necessary.

REFERENCES

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WELLERITES MOHRI Plummer & Scott

Pl. Pl. 1, figs. 5-9; text-figs. 7, 8

Wellerites mohri PLUMMER & SCOTT, 1937, Texas Univ. Bull. 3701, p. 376, 377-378, pl. 38, figs. 13-16; ----------, 1938, Geol. Soc. Amer., Bull., v. 49, p. 1920; SHIMER & SHROCK, 1944, Index foss. N. Amer., p. 575, pl. 236, figs. 7, 8; MILLER & STURGEON, 1946, Jour. Paleont., v. 20, p. 388; MILLER & FURNISH, 1957, Moore Treatise, Pt. L, p. 66, text-figs. 99, 100.

Walkerites mohri SMITH, 1938, The cephalopod fauna of the Buckhorn asphalt, p. 32.

Walkerites plummeri SMITH, 1938, ibid., p. 32-33, pl. 2, figs. 22, 23.

Walkerites vulgaris SMITH, 1938, ibid., p. 31-32, pl. 2, figs. 24, 25.

Wellerites sp., MILLER & STURGEON, 1946, Jour. Paleont., v. 20, p. 387-389, pl. 56, figs. 6-9; UNKLESBAY, 1954, ibid., v. 28, p. 85, 86, 91, 92.

?Wellerites russiensis RUZHENCEV, 1952, Akad. Nauk SSSR, Doklady, t. 84, p. 133-134.

The material now available is adequate for an understanding of this species. The conch is discoidal; phragmocone attains a diameter

TEXT-FIG. *3*—Synonymy under species heading. Such a listing may include all known references, but need not repeat a long series published previously. This abbreviated reference form merely cites an article listed at the end of the paper—for convenience, title of periodical or book may be given as well. Plate number references (*e.g.*, Pl. 1) will involve subsequent editorial marking and should be indicated in the left margin.

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TEXT-FIG. 4—References may be entitled "Bibliography, etc." The general form has been standardized in this *Journal* for years, but details have varied. The purpose is, of course, to provide the reader sufficient information for identifying and locating the article. The usual tendency is overabbreviation; the editor can strike out superfluous data easily, but is unable to add that which is lacking All typescript is double-spaced.

TEXT-FIG. 3 -- Immature external sutures of Schistoceras and Pintoceras.

A. S. hyatti Smith. Presumably from the Upper Pennsylvanian Canyon Group, north-central Texas, X6. From Plummer & Scott--the only figure these authors employed to portray their genus Pintoceras.

B. P. turkestanicum (Ruzhencev). From the Middle Pennsylvanian Jigulian Series, Turkestan Range, Central Asia, U.S.S.R.; at diameter of 10½ mm., X6. From Ruzhencev.

C. P. unicum (Miller & Owen). From the Seminole Formation, basal Missourian, Tulsa County, Oklahoma; based on the holotype (S.U.I. 13477), X6.

D. P. postvenatum Plummer & Scott. From the Middle Pennsylvanian Strawn Group, Kimble County, central Texas; based on figured homeotype (Texas Bur. Econ. Geol., P-8586), at a diameter of 15 mm., X5.

TEXT-FIG. 4 -- A Pennsylvanian phylogenetic sequence from the Midcontinent region emphasizing progressive modification in the umbilical portion of the suture.

A. Brannerоceras branneri (Smith). From the Lower Pennsylvanian Morrow Group, Boone County, northwestern Arkansas; based on a hypotype (S.U.I. 1975) at a diameter of about 45 mm., X2.

TEXT-FIG. 5—Text-figure legends are run, in order, as text at the end of the manuscript. Figures reproducible in this fashion involve only a fraction of plate cost and are to be designated by letters rather than numbers. All except brief explanation should be incorporated in the systematic text. The notation "from" suggests no more than moderate adaptation, whereas "after" may involve modification of the original figure. Approximate desired position in the final printed page is to be indicated in the margin of galley proof.

EXPLANATION OF PLATE 1

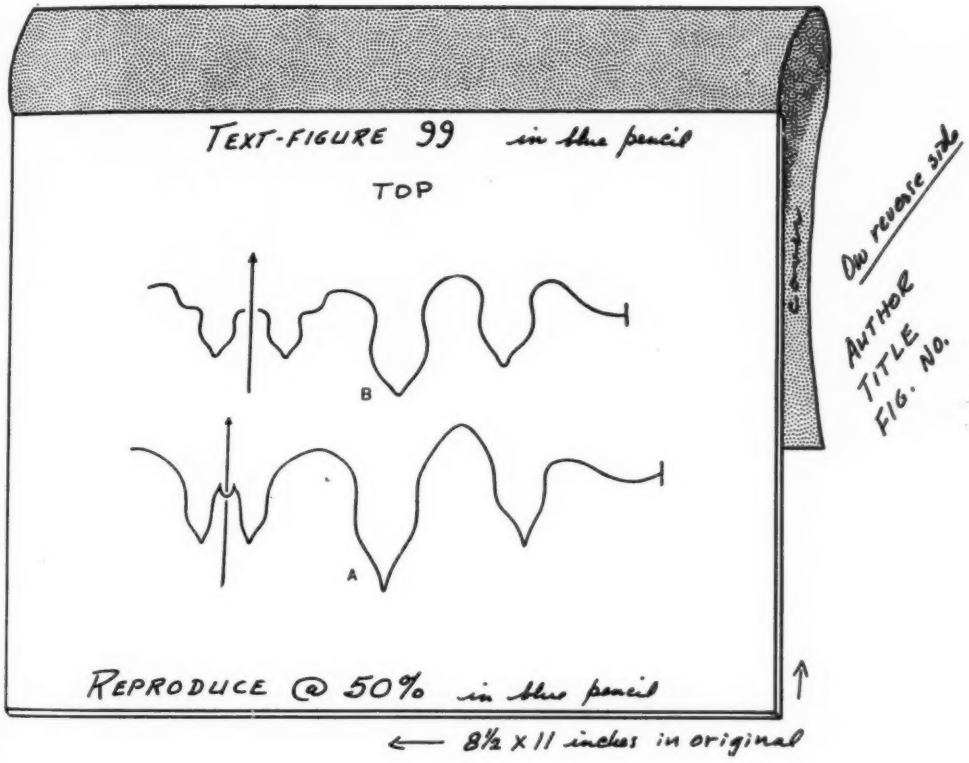
FIG. 1-4--Pintoceras unicum (Miller & Owen). Two topotypes (S.U.I. 1961) from the Seminole Formation south of Collinsville, Tulsa County, Oklahoma, X4 and X2½. 1, Figure is reversed and actually represents opposite side of specimen.

5-9--Wellerites mohri Plummer & Scott. 5, 6, Small specimen (S.U.I. 13845) which exposes inner volutions, from the Wewoka Formation about 7 mi. east of Ada, Pontotoc County, Oklahoma (sec. 4, T. 3 N., R. 7 E.), X5; 7, large specimen (S.U.I. 1958) from the Buckhorn Asphalt about 3 mi. south of Sulphur, Murray County, Oklahoma (sec. 2, T. 1 S., R. 3 E.), X1; 8, 9, specimen (S.U.I. 13844) from the Millsap Lake Formation about 1 mi. east of Millsap, Palo Pinto County, Texas, X1.

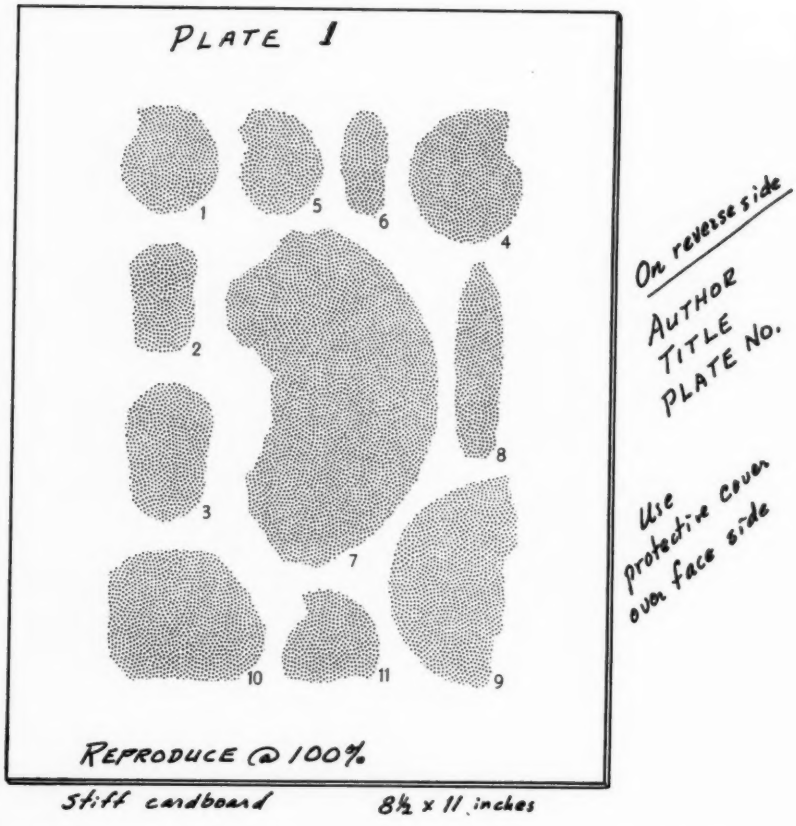
10--Winslowoceras sp. A cast of the inner volutions (S.U.I. 1959) from the Lower Pennsylvanian of the Arbuckle region in south-central Oklahoma, X3½.

11--Paralegoceras iowense (Meek & Worthen). Immature specimen (S.U.I. 1414) from the Smithwick Shale east of Rochelle, McCulloch County, Texas, X3.

TEXT-FIG. *6*—Plate legends are first set up in type as a separate portion of the manuscript.



TEXT-FIG. 7—Example of line drawing to be reproduced as cut in text.



TEXT-FIG. 8—Example of plate to be reproduced as full-tone insert, outlines of the figures only.

JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 383-384, MARCH, 1958

REVIEWS

EOCENE AND OLIGOCENE OSTRACODA OF BELGIUM, by Adriaan Jan Keij. Institut Royal des Sciences Naturelles de Belgique, Mémoire no. 136, 210 p., 23 pls., 9 figs., 16 tables, location maps, March, 1957.

The highly fossiliferous Eocene and Oligocene rocks of Belgium have been studied for well over a century by pioneer geologists. These outcrops are famous since they represent several type localities of the European standard geologic section. Type localities of commonly accepted stages like Ypresian (early Eocene), Ledian (early late-Eocene), Wemmelian (=Bartonian, later-late-Eocene), Tongrian (early Oligocene), Rupelian (middle Oligocene), lie in Belgium. Detailed studies of the microfauna of these sediments are of great importance because all later correlations throughout the world were made by comparison of faunas with these type sections. The only early record of the description of ostracodes from these sediments is in a monograph by Bosquet (1852) on the Tertiary ostracodes of Belgium and France. However, only one Eocene locality from Belgium is covered by Bosquet as against 27 from the Paris Basin. Although Bosquet's memoir remains the classic literature of Tertiary ostracodes, a modern revision was necessary because ostracode classification has undergone drastic changes since Bosquet's time. Keij has made an outstanding contribution to paleontology in his study of Eocene-Oligocene ostracodes of Belgium and by re-examination of Bosquet's type material.

Keij examined samples from a great many localities covering the entire Eocene-Oligocene except late Oligocene which does not outcrop in Belgium. Outcrop samples were supplemented by several borings in the type areas. The ostracode fauna contained in the Belgium sediments is compared by Keij with material from the upper Ypresian of Cuise-Lamotte, the upper Lutetian of Grignon, both in the Paris Basin; from the type Bartonian of Barton Cliff and from the lower Miocene of the Acquitaine Basin.

Keij's monograph on the Eocene-Oligocene Ostracoda of Belgium, opens with a chapter on Stratigraphy, which contains notes on the general stratigraphy of the area, together with lists of locations from which samples were collected. Five detailed maps show the exact location of samples and two lithologic logs show the correlation of bore holes. The next chapter is on Fauna and Keij discusses the distribution of 160 species and two varieties of ostracodes. A check list, which appears as table 1, summarizes the distribution of ostracode fauna in the Ypresian, Lutetian, Bartonian, Ledian, Tongrian and Rupelian. There is a separate chapter on the Bosquet's collection and Keij ably gives the Bosquet's original determination and the new determination of Bosquet's specific identifications. Keij has selected lectotypes of 34 species and a neotype of another one of Bosquet's species. The original and the revised determinations of Van Riemsdijk's collection (in the Geological Institute of Utrecht) are also given. The stratigraphic distribution of ostracodes in the Bosquet's collection is summarized in tables 2 through 5. The rest of the monograph contains systematic description of the fauna. Twenty-three plates, most of which are colotype reproductions of beautiful retouched photographs or pen drawings, appear in the end.

Keij reports 160 species and two varieties from Eocene-Oligocene; 40 species and two varieties are described as new. Four genera (*Boldella*, *Bosquetina*, *Kingmaina* and *Ruggieria*) and one subgenus (*Goerlichia*) are described as new.

The Paleontological Department of the Mineralogical Geological Institute of the State University of Utrecht is to be congratulated for sponsoring this study in a classic area and the Royal Institute of Natural Sciences of Belgium should be commended for publishing this volume. It is an excellent example of fine printing; especially the superb reproduction of plates.

REFERENCE

BOSQUET, J., 1852, Description des Entomostracés Fossiles des Terrains Tertiares de la France et de la Belgique: Acad. Roy. Sci., Lettres, Beaux-Arts de Belgique, Mém. couronnés et Mém. Savants étrangers, v. 24, 142 p., 6 pls.

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JOURNAL OF THE PALEONTOLOGICAL SOCIETY OF INDIA.

This year marked the appearance of a new journal devoted to paleontology, "Journal of the Palaeontological Society of India." The new journal is the publication of the newly organized Palaeontological Society of India, which was founded in 1950. This, our most recently formed paleontological society, has outlined an ambitious program which will do much to stimulate research in paleontology; even a cursory glance at the contents of the inaugural number gives one the assurance that the society aims at maintaining a very high standard of publication.

The impressive inaugural number of 265 pages contains 31 articles by prominent paleontologists of India as well as other parts of the world. The papers are both general and specific; "Paleontology and Evolution" by L. M. Davies and "Facies, Faunas and Formations" by H. S. Puri exemplify the former, whereas "Foraminifera of the Genera *Fabiania* and *Eorupertia* from Sylhet Limestone, Assam" by Y. Nagappa and "Calcareous Algae from the Upper Permian of the Dolomites (Italy) with Stratigraphy of the 'Bellerophon Zone' " by B. Accordi illustrate the latter type of contribution. The journal is $8\frac{1}{2}\times11$ inches printed on coated paper. The illustrations are line drawings and fine-screen half-tones.

The Palaeontological Society of India is to be complimented on preparing a biannual journal of such a high caliber. If succeeding issues fulfill the expectations promised by the inaugural number, as will certainly be the case, the new journal should receive wide support and prove to be one of our leading journals.

Membership in the Society is open to paleontologists throughout the world. Dues for fellows outside India are Rs 25/ (approximately $5.25) as admission fee and Rs 15/ (approximately $3.15) as annual fee. Those desiring applications for membership or subscription rates should write to: Dr. H. S. Puri, Florida Geological Survey, P. O. Drawer 631, Tallahassee, Florida.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 2, P. 385–399, MARCH, 1958

SOCIETY RECORDS AND ACTIVITIES

PROGRAM FOR S.E.P.M., LOS ANGELES MEETING

Stuart A. Levinson, Technical Program Chairman

RESEARCH COMMITTEE SYMPOSIUM: SILICA IN SEDIMENTS

1. INTRODUCTION, H. A. Ireland, University of Kansas, Lawrence, Kansas
2. THE GEOCHEMISTRY OF SILICA IN SEDIMENTARY ENVIRONMENTS, Konrad Krauskopf, Stanford University, Stanford, California
3. THE REMOVAL OF SILICA FROM MISSISSIPPI RIVER WATER AS IT ENTERS THE GULF OF MEXICO, George B. Bien, David E. Contois, and William H. Thomas, Scripps Institution of Oceanography, La Jolla, California
4. BEHAVIOR OF SILICA DURING DIAGENESIS, E. C. Dapples, Northwestern University, Evanston, Illinois
5. PETROLOGY AND GEOCHEMISTRY OF SILICA CEMENTATION IN SOME PENNSYLVANIAN SANDSTONES, Raymond Siever, Harvard University, Cambridge, Massachusetts
6. SILICEOUS ORGANIC REMAINS IN PELAGIC SEDIMENTS, William R. Riedel, Scripps Institution of Oceanography, La Jolla, California
7. PRESSURE SOLUTION AND POROSITY. Alan Thomson, Shell Oil Company, Midland, Texas
8. OPAL IN THE OGALLALA FORMATION IN KANSAS, Ada Swineford and Paul C. Franks, State Geological Survey, Lawrence, Kansas
9. SILICA IN EDWARDS LIMESTONE, TRAVIS COUNTY, TEXAS, J. S. Pittman, Jr., Phillips Petroleum Company, Bartlesville, Oklahoma
10. SILICEOUS SEDIMENTS IN UPPER PALEOZOIC ROCKS OF PART OF THE CORDILLERAN REGION, Harold J. Bissell, Brigham Young University, Provo, Utah
11. CHERTS AND NOVACULITES OF OUACHITA FACIES, August Goldstein, Jr., Bell Oil and Gas Company, Tulsa, Oklahoma

PALEONTOLOGY AND STRATIGRAPHY

1. A NEW METHOD OF FORAMINIFERAL CORRELATION, W. E. Hendrix, Standard Oil Company of California, Los Angeles, California
2. TERTIARY REEFS OF SOUTHERN LOUISIANA, McLain J. Forman, Atwater, Cowan and Assoc., New Orleans, Louisiana
3. SEDIMENTARY FRAMEWORK OF AN ABANDONED MISSISSIPPI DELTA, Charles R. Kolb and Jack R. Van Lopik, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi
4. CALIFORNIAN PLEISTOCENE PALEOTEMPERATURES, James W. Valentine and Robert F. Meade, University of California, Los Angeles, California
5. ELECTRONIC DATA PROCESSING AS A MEANS OF DETERMINING FOSSIL COMMUNITIES, John Imbrie, Columbia University, New York, N. Y.
6. THE DISTRIBUTION AND ECOLOGY OF RECENT FORAMINIFERAL ASSEMBLAGES FROM THE EASTERN MARGIN OF THE MISSISSIPPI DELTA, Robert R. Lankford, University of California, Scripps Institution of Oceanography, La Jolla, California
7. MEASUREMENT AND ERROR IN REGIONAL STRATIGRAPHIC ANALYSIS, W. C. Krumbein, Northwestern University, Evanston, Illinois
8. MIDDLE PENNSYLVANIAN SCHISTOCERATIDAE (AMMONOIDEA), A. K. Miller and W. M. Furnish, State University of Iowa, Iowa City, Iowa
9. OSTRACODE BIOFACIES AROUND SANTA CATALINA ISLAND, CALIFORNIA, Daniel J. Jones, University of Utah, Salt Lake City, Utah
10. MICROFAUNAS OF THE SACRAMENTO VALLEY, Andrew W. Marianos and R. Zingula, Humble Oil and Refining Company, Chico, California
11. CONODONT CONTROL OF PELLET FORMATION IN THE BASAL MAQUOKETA OF IOWA (To be read by title only), Paul Tasch, University of Wichita, Wichita, Kansas

SEDIMENTARY PETROLOGY AND MINERALOGY

1. THE SOLUBILITY OF $CaCO_3$ IN SEA WATER, Patrick H. Monaghan, Humble Oil and Refining Company, Houston, Texas
2. MINERALOGY OF FORAMINIFERA AS RELATED TO THEIR CLASSIFICATION AND THEIR ECOLOGY, Paul D. Blackmon and Ruth Todd, U. S. Geological Survey, Washington, D. C.

3. SILURIAN REEFS IN GOTLAND, M. G. Rutten, University of Utrecht, Utrecht, Netherlands
4. SPIRAL STRUCTURES AND ASSOCIATED MICRO-SLUMPING FEATURES IN LIMESTONES, Albert Carozzi, University of Illinois, Urbana, Illinois
5. ETCHED MINERALS IN WEATHERED PLEISTOCENE TUFFS OF ST. VINCENT, BRITISH WEST INDIES, Richard L. Hay, University of California, Berkeley, California
6. MINERALOGY AND STRATIGRAPHY OF THE MOLAS FORMATION, SOUTHWESTERN COLORADO, Richard M. Winar and William M. Merrill, Carter Oil Company, Carmi, Illinois, and University of Illinois, Urbana, Illinois
7. SEDIMENTARY FACIES AND THE PETROGENESIS OF CHERT, Louis I. Briggs, University of Michigan, Ann Arbor, Michigan

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The Permian Basin Section of the S.E.P.M. announces its 1958 Spring Field Trip—"Cretaceous Platform and Geosyncline, Culberson and Hudspeth Counties, Trans-Pecos Texas." The date of this trip is April 10–12, 1958. Registration will be at Van Horn, Texas, on the afternoon of April 10.

Prof. R. K. DeFord of the University of Texas and Dr. John P. Brand of Texas Technological College will be joint leaders of the trip. Localities in the Apache Mountains, Wylie Mountains, Van Horn Mountains, and Indio Mountains will be studied.

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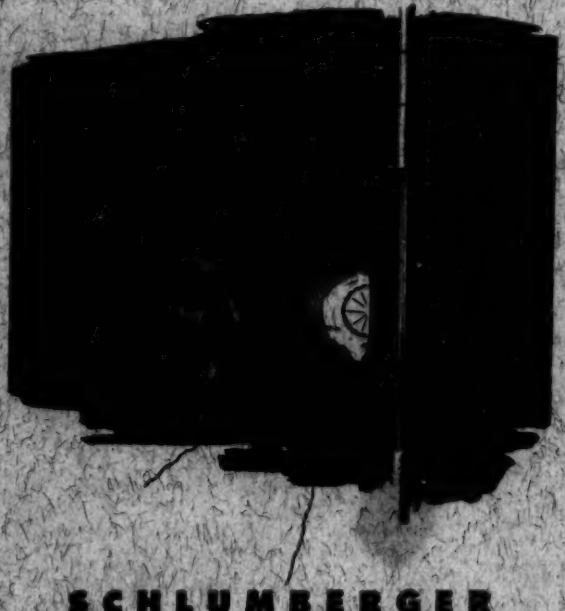

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